BLOCK 1 INTRODUCTION TO FOOD SCIENCE AND TECHNOLOGY

The science of food is the study of food components, their behavior under different environmental conditions, process of harvesting, milling, exposure to heat, cold, acid, alkalis etc. It covers all aspects of food raw material production, handling, processing, distribution, marketing and final consumption. For each food the processing methods evolved are based on their composition in terms of carbohydrates, proteins, fat, vitamin and minerals. Now food is a global commodity. Today, the field of food science has progressed from basic physical, chemical and biological reactions that take place during processing to the fields of biotechnology, food engineering, packaging and its effect on the consumer. New processing technologies now aim at not only increasing the shelf life but also retaining maximum organoleptic properties and qualities of fresh foods. The basic knowledge of food, its composition, need, effects of processing etc is essential in order to meet the demands of the market.

Unit 1 deals with **'Introduction to food science'**. After defining the food, its properties, constituents and chemistry are explained. Need of nutrition, digestive process, food spoilage and its effects are also discussed. This unit also covers the recent trends and new processes and equipments coming up in food processing. Food evaluation is discussed in brief.

Unit 2 is about **'Food processing industries'**. This unit explains about the world scenario of food processing, segments of food industries, status of food processing in India. It also covers problems and prospects of Indian food industries. The statuses of major food processing industries like cereal, pulse, horticultural crop, meat and fish industries are discussed. It also gives an overview of National Food Policy.

Unit 3 covers **'Food laws and associated bodies'**. Need pf food laws and standards are discussed. Indian and international food standards and regulatory bodies like PFA, FPO, MPO, BIS, AGMARK, AOAC, USDA, FDA, ISO, Codex Alimentarius are described. Quality assurance systems like HACCP, GMP and TQM are also discussed. This unit also gives an overview of export authorities of India, APEDA, MPEDA, NABL, and MFPI and their role. Product certification and licensing is also discussed in brief.

BPVI-001 FOOD FUNDAMENTALS

UNIT 1 INTRODUCTION TO FOOD SCIENCE

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- know constituents of food and properties;
- explain chemistry of food and nutrition;
- describe food spoilage and its effect; and
- discuss recent advances in food science and food evaluation.

1.1 INTRODUCTION – DEFINITION OF FOOD

Foods are materials, which in their naturally occurring, processed or cooked forms, are consumed by human beings for their nourishment, sustenance and enjoyment. Moreover food items are food grains (cereals: wheat, rice, coarse cereals like sorghum, millets etc.), legumes (pulses: red gram, black gram, green gram, beans), horticultural produce (fruits, vegetables, spices, condiments etc.), livestock produce (meat, egg, milk etc.) and fish (fish, prawns, crabs etc.). Beverages like tea, coffee, cocoa etc are also part of food.

Food sources in their natural form are cultivated, reared, captured or cultured. Some foods can be taken in raw form while most need some kind of processing to introduce desirable characteristics in them to make them acceptable, edible and digestible.

Food, as is known, is the essence of life. It is an exciting subject to study and know its importance and values. In earlier days human started experimenting on various forms and tastes. This led to the development of culinary art. Later on some people who developed special interest, became expert and earned name and fame. Much later it became a huge industry with a trade value of US$ two trillion.

Food Science and Food Technology can be defined as

Food Science: Food Science is the discipline in which the Biological and Physical Sciences and Engineering are used to study the nature of Foods, Causes of their deterioration and the principles underlying Food Processing.

Food Technology: It is the application of Food Science to the selection, preservation, processing, packaging, distribution and use of safe nutritious and wholesome food.

1.2 CONSTITUENTS OF FOOD, PROPERTIES AND THEIR SIGNIFICANCE

There are two important properties of food: nutritional value and taste (hedonic) value. The former is relatively easier to quantify since important nutrients are limited in number and their effects are more or less defined. Defining the taste is more difficult because it must take into account all those properties of food including visual appeal, smell, taste and texture, which interact with our senses. These properties are influenced by a large number of compounds, which in part have not been identified. Besides their nutritional and hedonic values, foods are increasingly being judged according to properties, which determine their handling.

1.2.1 Physical Properties of Foods

In broad sense, the physical properties of foods may be defined as those properties that lend themselves to description and quantification by physical rather than chemical means.

a) **Geometrical properties:** These encompass the properties of size, shape, volume, density and surface area as selected to homogeneous units. The geometrical characteristics of texture refer to structural geometry and structurally heterogeneous foodstuffs.

   Size and shape: The shapes of fruits and vegetables have been classified into 13 categories such as round, oblate, oblong, conic, elliptical, truncated, ribbed etc. the much prevailing method for quantitative shape description involves sphericity which is

   Sphericity = de/dc

   Where, **de** is the diameter of a shape of same as the test object and **dc** is its diameter of smallest circumscribing sphere (usually the longest diameter of the test object).

Size is usually characterized by determining the opening, as in sieve or screen, through which the product will or will not pass and measurement of diameter or length of product.

Volume, density and surface area: Volume and density measurement of liquid foods present no special problem, other than the proper control of temperature at which measurements are made. Standard volumetric methods (graduated cylinder) for volume quantification and pycnometer or commercial density meters for density measurement are simple. Volume of agricultural products, especially those exhibiting an irregular shape, is usually determined by water displacement. Density of solids can be determined by floatation in liquids (usually salt solutions) of different densities. Density of certain agricultural produce (peas, lima beans, potatoes) is an indirect measure of their texture also. Separation by density in floatation is also used with many agricultural commodities to remove defective materials and extraneous matter. Density is measured and defined in various ways like true density, substance density, particle density, apparent density and bulk density.

Surface area values have a meaning in heat transfer. A number of methods have been developed for calculating the surface area of products such as fruits etc based on shape factor measurement (e.g. areas of axial or longitudinal cross sections).

b) **Optical properties:** The most important optical properties from the quality point are colour and surface appearance (gloss) of the produce. These works on reflected light along with some spectrophotometer measuring light in both reflectance and transmittance modes. Transmitted light may be used for detecting defects such as water cores in apple.

Colour: It is one of the most important attributes and can separate a high quality produce (such as the golden yellow of a table orange) or can alert the consumer to a potential psychological danger (such as green processed meat). It also inferences flavour requirements in produce such as beverages and dessert gels and it affects consumer perceptions. Spectrophotometric method for colour description is based on three demarcations reflectance (lightness), dominant wavelength and purity. In this Hunter colour lab equipment colour scales L, a and b are used. L defines the lightness, a, the red-green lines and b the blue-yellow lines.

Gloss: The appearance of a surface, whether it is glossy or dull, is an important physical aspect of food quality detected by human vision. Typical of products where a shiny surface is valued as apples, cucumbers, cherries, on the other hand, oranges, green beans etc have dull surface. Gloss in the psychological attribute of surfaces associated with the spectrum reflects and can vary from surface to surface.

1.2.2 Rheological Properties

The complex nature of foods their variability and their diverse behaviour are some of the reasons for cataloguing separately the flow behaviour of specific foods.

The evaluation of rheological properties of solid foods can be divided into two broad classes. *Fundamental* tests measure properties that are inherent to the material and independent on the geometry of sample, the condition of loading or the apparatus e.g. modulus of elasticity, Poisson ratio, relaxation time, and shear modulus. *Empirical or imitator* tests are used to determine properties such as puncture force and extrusion energy where the mass of the sample, geometry, speed of test etc also determine the parameter estimated. The fundamental tests as applied to solid foods may again be classified into two essentially different groups: those divided under conditions of static (quasi-static) loading and those considered under dynamic conditions. Because foods are visco-elastic both time dependants and time independent measurements are required.

Foods that flow under gravity and do not retain their shape are considered to be fluid foods. Foods may exist as solids at one temperature and as liquid at other temperature (like ice-creams), suspension of solid matter is fluid media or emulsions. Because of wide varieties of their structure and composition, foods exhibit flow behaviour ranging from simple Newtonian to time dependent non-Newtonian and visco-elastic. For example, raw whole egg at 21 C was found to be a Newtonian fluid. However frozen egg was found to be a shear-thinning fluid.

1.2.3 Thermal Properties

Thermal properties are required to understand heat transfer during heating or cooling which foods are often subjected. Variability in composition and physical characteristics is typical for all food products.

The major thermal properties are specific heat, enthalpy, thermal conductivity, thermal diffusivity and heat transfer coefficient. These are much commonly used properties in designing a system for heating/ cooling of foods. These are several other properties that are thermal in value but are much less important to most heat transfer applications: melting/freezing point, latent heat, heat of respiration, heat of adsorption, coefficient of thermal expansion, dielectric constant, emissivity and absorptivity (radiation heat transfer).

1.2.4 Mass Transfer Properties

Mass transfer plays a very important role in basic unit operations of food processing. It is also involved in several physical, chemical and biological food processes such as salting, sugaring, oxygen absorption, de-aeration, and cleaning of process equipment. It is important in food processing and storage, where transfer of moisture; vapours/ gases and flavours components may influence food quality.

1.2.5 Electrical Properties

These properties determine the amount of energy coupled by a food product, its distribution within the product. Electrical properties are of most basic interest in high frequency food processing and their dielectric properties because these determine a number of related electrical properties, which affect energy coupling and its distribution within a food product. Biological material acts as heavy insulators i.e. non-ideal capacitors, in terms of their ability to store and dissipate electrical energy from an applied electromagnetic field by radiation transfer. These properties result form electric charging and less current generally related to materials electrical capacitance and resistance and are defined by fundamental dielectric properties.

1.3 FOOD CHEMISTRY: MOISTURE, CARBOHYDRATES, PROTEINS, LIPIDS, VITAMINS, MINERALS, AND PHYTO-CHEMICALS

Nutrients are naturally occurring chemical substances found in food. There are six categories of nutrients: proteins, lipids, carbohydrates, vitamins, minerals, and water. The chemistry of these nutrients influences the characteristics of our food. Proteins, fats, and carbohydrates in food provide the energy our bodies need to function.

1.3.1 Moisture

Every food material contains moisture. It is found in two forms i.e. free water and bound water. It is one of the most important attributes of the food material that affects processing, preservation and storage of foods. Fifty to 60 percent of human body weight consists of water. The fruits and vegetables contain 90% to 99%, fruit juices 80% to 89%, pasta, legumes, beef, and dairy 10% to 60%, and crackers and cereals contain 1% to 9% water.

1.3.2 Carbohydrates

The carbohydrates in diet come from plant foods. Simple carbohydrates include the different forms of sugar (monosaccharides and disaccharides); complex carbohydrates (polysaccharides) include starches and dietary fiber. Specifically they are composed of carbon and water and have a composition of $C_n (H_2O)_n$. No single carbohydrate is essential, but carbohydrates do participate in many required functions in the body. Carbohydrates may be divided into following categories.

Monosaccharides: It may have 6 carbons (called hexoses), or 5 carbons (called pentoses). Glucose (dextrose), fructose, and galactose are three common hexoses. Ribose and deoxyribose are two common pentoses.

Disaccharides: Two monosaccharides may be linked together to form a disaccharide. Sucrose (sugar) is the most common disaccharide and is made of one molecule each of glucose and fructose. Lactose is the major sugar in milk and is made up of one molecule of glucose and one of galactose. Maltose is a disaccharide made from two molecules of glucose.

Polysaccharides: Combination of more than two sugars is referred to as oligosaccharides, unless they are very large and then they are called polysaccharides. Raffinose and stachyose are two oligosaccharides. Nutritionally, polysaccharides are added to increase the dietary fiber content and functionally to thicken, form gel, bind water and stabilize proteins. Starch, cellulose, gums are main polysaccharides.

1.3.3 Proteins

Amino acids are building blocks of protein. Dietary protein is supplied from plant and animal sources. Proteins are polymers of amino acids. The shape and thus the function of a protein is determined by the sequence of its amino acids. Proteins must be broken down (hydrolyzed) to amino acids before they can be used. Once absorbed, amino acids are utilized to make proteins, converted to energy, or stored as fat. About 20 percent of the human body is made of protein.

Amino acids contain an amino group (-NH2) and an acid group (-COOH). There are twenty amino acids that are found in proteins. Amino acids join by forming peptide bonds. The conformation of a protein molecule in the native state is determined by the primary structure, the secondary structure, a tertiary structure.

Primary: The primary structure is the combination of amino acids in a proper sequence by means of the peptide bonds. No other forces or bonds are implied by this structural level designation.

Secondary: Secondary structure is that which forms a pleated or helix structure. The alpha helix is stabilized by hydrogen bonding between carboxyl and the amide groups of the peptide bonds that generally appear in a regular sequence along the chain of amino acids.

Tertiary: A tertiary structure is the folding of the coiled chain or chains. Covalent, hydrogen, and Vander Waals forces may be involved in the structural organization of protein molecules.

1.3.4 Lipids

Lipids include fats and oils from plants and animals. Lipids are the substances in foods that are soluble in organic solvents. This category includes fatty acids, triglycerides, phospholipids, pigments, vitamins, and cholesterol. Naturally occurring fatty acids have an even number of carbons. Reaction products of long-chain fatty acids are very important to the flavour of foods.

Fatty Acids: Fatty acids may be saturated or unsaturated (contain double bonds). A fatty acid that contains one double bond is called mono-unsaturated and with two or more double bonds is called polyunsaturated. Unsaturated fatty acids can exist in two forms, cis and trans, depending upon the arrangement of the portions of the fatty acid molecules around the double bonds. The double bonds in lipid molecules are highly reactive toward oxygen.

Triglycerides: Food fats are made up of three molecules of fatty acids connected to a molecule of glycerol and are known as triglycerides. The vast majority of foods contain fat in the form of triglycerides. Triglycerides are broken apart by lipases enzymes produces soapy flavour products. Triglycerides molecule that has had one fatty acid removed is called a diglyceride, two fatty acids removed is called a mono glyceride.

Phospholipids: Some fatty acids are connected to glycerol molecules that contain a molecule of phosphorus. These special lipids are known as phospholipids e.g. lecithin. They play important roles in the body but are not essential nutrients because the body can synthesize them in adequate quantities.

Cholesterol: Cholesterol is a compound produced by the body that has received considerable attention due to its reported link to heart disease. Some people have a genetic problem with the system that regulates cholesterol synthesis, and they produce excessive amounts. These people generally have greatly elevated serum cholesterol levels. This is of concern because high serum cholesterol is a risk factor for coronary heart disease.

1.3.5 Vitamins

Vitamins are chemical compounds in our food that are needed in very small amounts (in milligrams and micrograms) which regulate the chemical reactions in our body. The vitamins are divided into fat-soluble and water-soluble vitamins. Fat-soluble vitamins include vitamins A, D, E, and K. The water-soluble vitamins include the B vitamins and vitamin C. B vitamins include: thiamin, riboflavin, niacin, vitamin B_6, pantothenic acid, folic acid, biotin, and cobalamin (vitamin B_{12}).

1.3.6 Minerals

Minerals, which are also needed only in small amounts, have many different functions. Some minerals assist in the body's chemical reactions and others help form body structures. Minerals are important for energy transfer and as an integral part of vitamins, hormones, and amino acids. Depending on the amount in the body, minerals in the diet are classified as macro-minerals or micro-minerals (sometimes called trace minerals) as listed below:

Macro-minerals

Calcium	Chloride
Phosphorous	Magnesium
Potassium	Sulphur
Sodium	

Micro-minerals important in nutrition include:

Chromium	Molybdenum	Iodine
Cobalt	Silicon	Nickel
Copper	Tin	Selenium
Fluorine	Vanadium	Zinc
Manganese	Fluorine	

1.3.7 Phyto-chemicals

Phytochemicals exhibit diversified physiologic and pharmacologic effects. Active derivatives extracted from leaves, stems, roots, flowers, and fruits of plants may be classified into three main categories:

1. Toxic with no discernible therapeutic use; e.g. pyrrolizidine alkaloids, nicotine, and hydrazine derivatives

2. Toxic but useful for treatment of disease when used in controlled amounts; e.g. morphine, digitalis, and vinca alkaloids

3. Chemo preventative, useful against diseases; e.g. arteriosclerosis, cancer, and diverticular disease

Most active chemo preventative phytochemicals are high molecular-weight fibers such as celluloids, pectins, lignins, and low-molecular-weight compounds such as carotenoids, dithiolthiones, flavnoids, indole carbinols, isothiocyanates, mono- and triterpenoids, and thioallyl derivatives.

1.4 NUTRITION AND DIGESTION

1.4.1 Nutrient Needs

The requirement for a nutrient is that the minimum intake will maintain normal functions of the body and health. The main nutrients required by human beings are water, carbohydrates, protein, fat, vitamins and minerals. These are the source of energy. The nutrient needs of human beings are described below.

a) **Water:** Water is essential. About 65 percent of the adult body is made up of water. Lack of water can cause death more quickly than lack of any other nutrient. All the chemical reactions that occur in the body take place in water. Water also reacts during the chemical processes, regulates body temperature, transports nutrients and wastes, and dissolves nutrients. An adult should drink three to five litres of water each day.

b) **Carbohydrates:** Dietary carbohydrates include sugars, complex carbohydrates, starch and fiber. During digestion all carbohydrates except fiber break down into sugars. Sugars and starches occur naturally in many foods that also supply other nutrients. Examples of these foods include milk, fruits, some vegetables, breads, cereals, and grains.

c) **Fiber:** Fiber is found only in plant foods like whole-grain breads and cereals, beans and peas, fruits and vegetables. Eating a variety of fiber-containing plant foods is important for proper bowel function. Some of the health benefits associated with a high-fiber diet may come from other components present in these foods, not just from fiber itself. For this reason, fiber is best obtained from foods rather than supplements.

d) **Protein:** The nitrogen in protein is used for the synthesis of purines, pyrimidines, nucleic acids, adenosine triphosphate (ATP), hemoglobin, and cytochromes.

Depending on age and gender, humans require different levels of protein in their diet. Humans need the amino acids that the body cannot synthesize. These are known as essential amino acids. They include:

Phenylalanine	Methionine
Tryptophan	Valine
Histidine	Leucine
Isoleucine	Threonine
Lysine	Arginine

e) **Lipids:** In food, lipids are a source of essential fatty acids, gives that energy, act as carriers for flavours and fat-soluble vitamins, contributes to texture and mouth feel, is a pre-cursors of flavour, and provides heat transfer medium. The body can produce most of the fatty acids that it requires. It cannot make some fatty acids that contain double bonds. From linoleic acid (18 carbon fatty acid with two double bonds) humans can synthesize all the other fatty acids they require. Thus, linoleic acid is considered as an essential nutrient.

f) **Vitamins:** Table 1.1 lists the fat-and water-soluble vitamins and their functions.

Table 1.1: Functions of some vitamins

Vitamins	Some functions
Fat-Soluble vitamins	
Vitamin A	Growth and development of bone and epithelial cells, vision
Vitamin D	Absorption of dietary calcium and phosphorus
Vitamin E	Antioxidant in tissues
Vitamin K	Aids in blood clotting
Water-Soluble Vitamins	
Thiamin	Coenzyme in energy metabolism
Riboflavin	Coenzyme in many enzyme systems
Niacin	Coenzyme for cell respiration; release of energy from fat, carbohydrates and proteins
Vitamin C	Metabolism of amino acids, fats, lipids, folic acid, and cholesterol control, collagen formation
Vitamin B_{12}	Coenzyme for red blood cell maintenance and nerve tissue; carbohydrate, fat, and protein metabolism

g) **Minerals:** Table 1.2 lists some of the macro minerals and micro minerals and their functions.

Table 1.2: Functions of some minerals

Mineral	Some functions
Calcium	Bone mineral; blood clotting; nerve, muscle, and gland function
Phosphorus	Bone mineral, part of many proteins involved in metabolism
Iron	Part of haemoglobin and some enzymes, oxygen transport
Copper	Iron absorption, haemoglobin synthesis, skin pigments, collagen metabolism
Magnesium	Bone mineral, enzyme activator; energy metabolism
Sodium, Potassium, Chloride	Tissue fluid pressure and acid-base balance, passage of nutrients and water into cells, nerve and muscle function
Zinc	Activator of many enzymes
Iodine	Thyroid function
Manganese	Synthesis of bone and cartilage components, cholesterol metabolism
Selenium	Removal of peroxides from tissues, enzyme activation

1.4.2 Digestive Process

The processing of food takes place in four stages:

a) **Ingestion:** The act of eating. This is the first of the four main stages of food processing.

b) **Digestion:** Digestion breaks down food into molecules small enough to be absorbed. It breaks polymers into monomers that are easier to absorb and that can be used to synthesize new polymers required by the organism.

c) **Absorption:** Cells that line the digestive tract take up the nutrients. Nutrients are transported to the cells where they are incorporated into the cells and converted to energy that may be used immediately or stored until needed.

d) **Elimination:** In the last stage of food processing is elimination in which undigested wastes pass out of the digestive tract.

1.4.3 Components of the Human Digestive System

The following structures are considered parts of digestive system:

Mouth	Gall bladder
Tongue	Pancreas
Pharynx	Small intestine
Salivary glands	Large intestine
Esophagus	Rectum
Stomach	Anus
Liver	

1.4.4 Stability of Nutrients

The nutritive value of food starts with the genetics of the plants or animals. Fertilization, weather, maturity and harvest also influence the composition of the plant or animal being used for food. Storage before processing affects nutrient levels. Then all of the processing steps continue to affect the nutrient levels in a food. Finally, preparation in the home or at the restaurant can reduce the final nutritive value of a food before the digestive process.

Vitamin A is highly sensitive to acid, air, light and heat, vitamin C, D and thiamin to alkalinity, air, light and heat. Because of this sensitiveness, cooking losses of some essential nutrients may be in excess of 75%. A primary goal of food science is to preserve the nutrients through all phases of food harvesting, processing, storage, and preparation. Stability of nutrients under varying conditions of pH, air, light, heat, and cold is different. Nutrient losses are small in most modern food processing operations, but when nutrient losses are unavoidably high, the law allows enrichment.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the major properties of food? Define them.

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2. Describe the chemistry of carbohydrates and proteins?

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3. What nutrients are required to our body and what are their functions?

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4. Describe digestive process of human.

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1.5 FOOD SPOILAGE AND ITS EFFECTS

All foods have a time limit of their usefulness that depends on the type of food, the storage conditions, and other factors. Shelf life is the time required for a food product to reach an unacceptable quality. It depends on the food item, the processing method, packaging, and storage conditions. Food spoilage includes changes in organoleptic quality, nutritional value, food safety, aesthetic appeal, colour, texture, and flavour. To some degree, all cause negative changes in the food as much as possible.

1.5.1 Types of Food Deterioration

The three general categories of food deterioration are physical, chemical and biological. Factors that cause food deterioration are many, including light, cold, heat, oxygen, moisture, dryness, other types of radiation, enzymes, microorganisms, time, industrial contaminants, and macro-organisms (insects, mice, etc).

1.5.2 Causes of Food Deterioration

Specific causes of food deterioration include number of factors as described below. These items can cause deterioration individually or in any combination.

Bacteria, Yeast, Mold: Thousands of species of microorganisms exist, and few hundred are associated with foods. Not all are bad because some are desirable in food preservation. Bacteria are single-celled organisms occurring in three shapes: round (cocci), rod (bacilli), and spiral (spirilla and vibrios). Some produce spores, and these spores are resistant to heat, chemicals, and other adverse conditions.

Yeasts are the largest of the microorganisms but are still single cells, and some produce spores. Molds are larger than bacteria. They are often filamentous, and they all produce spores.

In foods, microorganisms attack all the food components-sugars, starches, cellulose, fats, and proteins. Depending on the food and the microorganism, the action on food could be to produce acids, making the food sour, or produce alcohol. Some microorganisms produce gas, making the food foamy; still others produce unwanted pigments or toxins.

Environmental conditions that affect microbial growth include temperature and oxygen. Microbes that prefer cold temperatures are said to be pyschrophilic. Mesophilic microorganisms prefer normal temperatures; thermophilic microorganisms prefer hot temperatures. Bacteria or moulds that require atmospheric oxygen are said to be aerobic, and those yeast and bacteria that do not require atmospheric oxygen are called anaerobic. Facultative microorganisms are both aerobic and anaerobic; obligative microorganisms are either.

Insects: Insect damage can be minor, but the wounds facilitate additional damage by microorganisms. Insect damage and infestation can also be so much that it can make the food inedible.

Food Enzymes: All foods from living tissues have enzymes. At the time of harvest or slaughter, enzymes that control digestion and respiration proceed uncontrolled and cause tissue damage. Some of the post-harvest enzymatic reactions are desirable-for example, the ripening of tomatoes and the aging or tenderizing of beef. Heat, chemicals, and radiation can control enzyme action.

Heat and Cold: The higher the temperature, the faster the biochemical reactions. In fact, the rate of chemical reactions doubles with each 10-degree rise in temperature. On the other hand, subfreezing temperatures damage tissues. Cold temperatures may also cause discoloration, change the texture, break an emulsion, and denature protein. Chilling can injure the tissue of fruits.

Oxygen: Chemical oxidation reactions can destroy vitamins (especially A and C), alter food colours, cause off-flavours, and promote the growth of moulds.

1.5.3 Food-Borne Disease

Food infections are caused when a microorganism is present in the food and it causes infections in the human when the food is consumed. *Clostridium perfringen*, *Salmonella* sp., *Escherichia coli* and several others can cause infections. Food intoxication occurs when a food is consumed that contains chemical toxins which poison the humans. *Staphylococcus aureus* and *Clostridium botulinum* both produce toxins.

Microbes associated with disease: Disease-causing organisms that are associated with foods are very important from both a human health perspective and from economical perspective. The diseases that are caused by microbes associated with food are grouped into three categories: infections, intoxications, and toxico-infections.

Food-borne intoxications: Intoxications are the result of the ingestion of a toxin that is produced by a microbe living on the food product. The toxins that are produced by these organisms usually have a long half-life, even if the microorganism have died, the toxin remains. Intoxications also differ from infections in that the symptoms usually occur within hours after ingestion, instead of the days that are normally associated with food borne infections. Toxin producing strains of *Staphylococcus aureus* are responsible for staphylococcal food poisoning. It can be found in nasal passages, skin and throats of human. Most of these toxins are stable, even under heating conditions. The infective dose for the toxin is between 100-200 nanogrms.

Mycotoxins: Mycotoxins are toxins that are produced by molds that have the ability to grow on food products. Different species of *Aspergillus* and *Penicillium* can produce mycotoxins. Depending on the type of food and the conditions, the mold may be present or absent, even if the mycotoxins remains. Foods associated with mycotoxins include grains, such as corn, wheat, beans, rice and groundnut. If moisture is introduced, molds can grow and form mycotoxins. These toxins are then transferred into the food product that is made from the initial material.

1.6 RECENT TRENDS IN FOOD PROCESSING AND PRESERVATION

New food products and safe foods require new food processing methods and systems. In recent trends, firms exercising control over several stages of food production may increasingly dominate the food industry. This refers to the way products are acquired or traded in a market. Food industry firms form three basic types of vertical coordination.

Open production: A firm purchases a commodity from a producer at a market price determined at the time of purchase.

Contract production: A firm commits to purchase a commodity from a producer at a price formula establish in advance of the purchase. The contract farming comes in this group.

Vertical integration: A single firm controls the flow of a commodity across two or more stages of food production.

The food industry has traditionally operated in an open production system. However, more discriminating consumers, plus new technological developments that allow farm product differentiation, are contributing to a decrease in open production and vertical integration. Changing demographics and the increasing value of a person's time contributed to consumer preferences for a wide variety of safe, nutritious and convenient food products.

Providing food products with specific characteristics preferred by more discriminating consumers will likely involve increasingly more detailed raw commodity products, such as frying chicken of a specific weight and size, or a corn kernel with a specific protein content. This effort to carefully tailor raw commodities with processing in mind is already underway in food industries.

1.7 NEW PRODUCTS AND EQUIPMENT

The kind of food consumed is changing continuously and contributing to the competition and marketing. Over 10000 products are introduced each year in food processing sector. The initial focus of research was to reduce post-harvest losses through improved drying and storage technologies. Later research led to advances in processing techniques for food and feed. Latest research is being carried out to bring about improvement in safety and quality.

New industrial applications evolved, such as new forms of heat processing, low energy production, pasteurization, semi-finished production techniques (filtration, extraction, centrifugation), chilling and freezing. Now, computers are being used to develop sophisticated monitoring systems for instance scientists have developed computer sensors that continually measure plants 'vital signals' such as tissue temperature, and swelling and regulate the irrigation and atmospheric gas concentrations accordingly. Packaging technologies like vacuum packaging of milk have also improved.

Better grain storage techniques and post-harvest management allow developing countries with humid tropical climates to compete in the world grain markets with virtually insect free exports from temperate zones. Recent developments in biotechnology are fostering more concentrated seed production, vertical integration of production and processing and the need for segregated handling system to preserve the identity of distinct products.

New processes are continuously being tried in unit operations. New processes, which are coming up now, are Ohmic heating, irradiation, supercritical fluid extraction and high hydrostatic pressure technologies.

The success of freezing technology has opened a new field for food processors. Complete meals are being prepared now which are frozen until the consumer is ready to thaw and heat them. Many of these meals are sold in serving dishes. Other frozen foods, which are now coming up, are potpies, fish sticks, desserts and potatoes. Additives, food composition standards and labelling are also leading to the development of new products and machineries.

1.8 FOOD EVALUATION

Variety, season, geographical differences, harvesting, handling, processing, packaging, storage, display, home preparation, cooking, and serving influence nutrient content of foods. The food composition is determined by a variety of scientifically sound, standardized methods. The first system of approximating the value of food for nutritional purposes was developed at the Weende Experiment Station in Germany more than 100 years ago. This system separates a food into nutritive fractions. This system was known as proximate analysis. Various methods are developed to evaluate protein, carbohydrate, fat, vitamins and mineral, and fiber in the food. Some of the methods are standards developed by the Government organizations for quality analysis. Number of equipment and processes are also available for proximate analysis of food destructively or non-destructively. Newer methods of determining the composition of foods have replaced or supplemented the old proximate analysis and allowed determination of more specific nutrients in foods. These include spectrophotometry, liquid chromatography, and gas chromatography, which allow the determination of fatty acids, cholesterol, amino acids, specific minerals, and vitamins.

Food composition tables are used to evaluate the nutritional value of food supplies, to develop food distribution programs, to plan and evaluate food consumption surveys, to provide nutritional counselling, and to estimate the nutritional content of individual diets. The parameters that are evaluated for food evaluation are.

Description of food and measure
Moisture
Food energy (in Joules)
Protein, fat, different fatty acids (saturated, monounsaturated, polyunsaturated fatty acids and cholesterol), and carbohydrate (in grams)
Vitamins and Mineral (in milligrams and IU)

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the main causes of food deterioration and what are their effects?

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2. What do you understand by food evaluation?

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1.9 LET US SUM UP

Food is essentially required for human being for energy. Nutrition is the processes by which the foods people eat provide the nutrients they need to grow and stay healthy. There are six categories of nutrients: proteins, carbohydrates, lipids, vitamins, minerals and water. The chemistry of these nutrients influences the characteristics of the food.

Food deterioration includes changes in organoleptic quality, nutritive value, food safety, aesthetic appeal, colour, texture and flavour. To some extent, all food undergoes deterioration after harvest. Deterioration may be physical, chemical or biological. Some deterioration produces toxins that are not destroyed by heat. Some of toxins produced by microorganisms can cause infections in humans.

The kind of foods people eat change in response to many influences such as demographic shifts, supply of ingredients, availability and costs of energy, politics, scientific advances in nutrition, health and food safety. New processing methods and approaches are coming up in food science.

The digestive process includes ingestion, digestion, absorption and elimination. Nutrients in the diet are progressively broken into smaller components by mechanical, chemical, and enzymatic means. Small molecules resulting from digestion are absorbed to supply the body with energy, protein, vitamins and minerals.

Food composition tables are used to evaluate the nutritional value of food supplies, to develop food distribution programs, to plan and evaluate food consumption surveys, to provide nutrition counselling and to estimate the nutritional content of individual diets.

1.10 KEY WORDS

Food : Foods are materials, which in their naturally occurring, processed or cooked forms, are consumed by human beings for their nourishment, sustenance and enjoyment.

Food infection : Illness produced by the presence and growth of pathogenic microorganisms.

Lipids : A broad group of fat like substances with similar properties.

Minerals : Minerals are needed only in small amounts and have many different functions in the human body.

Nutrition	:	It is the processes by which the foods people eat provide the nutrients they need to grow and stay healthy.
Nutrient needs	:	It is the minimum requirement for a nutrient intake that will maintain normal functions and health.
Protein	:	Large molecules of long chains of amino acids.
Properties of foods	:	Properties of foods include physical, rheological, electrical, thermal and optical properties of foods.
Triglycerides	:	Neutral fat molecule made up of three fatty acids joined to one glycerol molecule through a special chemical linkage called ester.
Vitamins	:	Vitamins are chemical compounds in our food that are needed in very small amounts to regulate the chemical reactions in our bodies.

1.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include following points:
   - Geometric, rheological, thermal, electrical and mass transfer properties;
   - Significance of these properties.
2. Your answer should include following points:
   - Chemical composition and bonding.
   - Classifications.
3. Your answer should include following points:
   - Nutrients needed.
   - Significance, functions in body.
4. Your answer should include following points:
   - Digestive process.
   - Components of digestive system.

Check Your Progress Exercise 2

1. Your answer should include following points:
   - Physical, chemical and biological causes
   - Disease and other effects
   - Mycotoxins and intoxications
2. Your answer should include following points:
   - Proximate analysis
   - Food evaluation table

1.12 SOME USEFUL BOOKS

1. Fellows, P.J. (1998) Food Processing Technology, Principles and Practices. Woodhead Publishing Limited. Cambridge, England.

2. Parker, R. (2003) Introduction to Food Science. Thomson Learning Inc. New York.

3. Potter, N.N. and Hotchkiss, J.H. (1995) Food Science, 5th Edition. Chapman & Hall Publishing Inc, New York.

4. Potter, N.N. (1987) Food Science. S.K. Jain for CBS Publishers & Distributors, New Delhi.

5. Potty, V.H. and Mulky, M.J. Food Processing. Oxford & IBH Publishing Co. Private Limited, New Delhi.

UNIT 2 FOOD PROCESSING INDUSTRIES

Structure

2.0 OBJECTIVES

After reading this unit, you should be able to:

- know scenario of food processing industries in India and world;
- explain trends of consumption of processed food;
- describe problems, prospects and status of food processing industries;
- learn about livestock and aquacultural processing industries; and
- explain national food processing policy.

2.1 INTRODUCTION

Food processing industries are major industries in developed countries. In developing countries, it is in growing stage. The food processing industires include cereals, pulses, oilseeds, bakery, horticultural crops, livestock and aquacultural produce etc. Now food is a global commodity and hence its processing industries will play important role in economy of any country. Type of food is now governed by consumers. The food processing in india is mainly done by unorganized sectors. So, there is a need to know the status of food procesing industries in india. The present unit covers the status of food processing industries in india, trends of food consumption, major processing industires of India and National Food Processing Policy.

2.2 FOOD PRODUCTION IN INDIA AND WORLD, PROCESSING AND VALUE ADDITION

The global food industry, with a value of US$ 2.2 trillion annually, is the single most important industry in the world economy. Food industry is expected to be worth $ 10 trillion by 2028 and most of this growth will come from developing world. The direct impact of the sub sector on growth and indirect stimulus to other type of economic activity carry important implications for employment, exports, food security and living standards. The development of food industries mainly depends upon the raw material coming from agriculture. The production of food grains of the world and percent share of India is given in Table 2.1.

Table 2.1: Production of major agricultural commodities and India' share in 2001

S.No.	Commodity	World production ('000 tons)	% Share of India
1.	Paddy	601128	21.9
2.	Maize	602814	1.9
3.	Wheat	585421	12.3
4.	Groundnut (in shell)	33802	17.7
5.	Sugarcane	1259906	23.3

On an average, agro-industries accounts for about 2% of GDP in developing countries but 9% in developed countries. The value of agro-processing is about three to four times that of agriculture in developed world, while it is typically a fraction of the value of agriculture in developing world. In developed countries, the share of total value added products in agro industries is 20-30%, whereas in developing world it is 30-45%.

The distribution of agro-processing industries within the developing world is relatively unequal. In 1997, 40% of agro-processing value added products in developing countries were concentrated in South and East Asia and Latin America. Among the developing countries, India ranked fourth with 9% value added products of the contribution from developing world. Trade in food products is increasing with a growth rate of 9.4% each year compared with an annual growth of 2.1% for agricultural commodities. Growth has been concentrated among developed countries. About 85% of European Union food exports are processed food while 60% of African export are primary commodities.

Now food is a global commodity. Food is traded and shipped around the world. The modern grocery store sells food from all over the world. These food might include cheese from Europe, beef from Australia, strawberries from Mexico, and apple from Argentina. The food processing industries are opening subsidiaries in other countries and fast food companies are opening outlets all over the world. Globalization and WTO will affect the world food processing industries to a great extent with the new global standards and food safety regulations.

2.3 PARTS OF THE FOOD INDUSTRY

The food industry is divided into four major segments:

i) Production
ii) Manufacturing/processing
iii) Distribution
iv) Marketing

Production: Production includes such activities as farming, ranching, orchard management, fishing and aquaculture. Technologies involved in production of the raw materials include the selection of plant and animal varieties, cultivation, growth, harvest, slaughter, and the storage and handling of the raw materials.

Manufacturing/processing: Manufacturing converts raw agricultural products to more refined or finished products. Manufacturing requires many unit operations and processes that are at the core of food sector.

Distribution: Distribution deals with those aspects conducive to product sales, including: product form, weight and bulk, transportation, storage requirements and storage stability.

Marketing: Marketing is the selling of foods in raw and processed form and involves wholesale, retail, institutions and restaurants

These four divisions are rather artificial as these actually overlap one another. Nevertheless, the food industry requires planning and synchronization in all its divisions to be successful. Another way of dividing the food industry is along major product lines:

- Cereals and bakery products
- Meats, fish and poultry
- Dairy products
- Fruits and vegetables
- Sugars and other sweets
- Fats and oils
- Non alcoholic beverages/alcoholic beverages

These divisions are typically where consumer consumption is measured and reported. Each segment can be divided into number of sub-segments. For example cereal processing may include wheat processing, pulse processing, bakery industries, weaning foods industries, fast food manufacturing etc.

Allied industries: Many companies do not sell food directly but they are deeply involved in the food industry. These are called allied industries. Allied industries produce non-food items that are necessary for marketing food. The packaging industry is a good example. Some specific examples include cans, food colour and flavour, paper products, and plastic products. Chemical manufacturers represent another group of allied industries. They supply the acidulants, preservatives, enzymes, stabilizers, and other chemicals used in foods. Monitoring and regulatory agencies such as the BIS, APEDA, FPO, Food & Drug Administration (FDA), lawyers, consumer action and information agencies, and other regulatory agencies are also part of allied industries.

2.4 TRENDS IN CONSUMPTION OF PROCESSED FOOD

Although expenditure on food has increased considerably over the years, the increase has not matched the gain in disposable income and hence percentage of income spent on food has declined. As income rises, the proportion spent for food declines.

Americans spent only about 8 percent of their personal consumption expenditures for food to be eaten at home. This compares with 10 percent for Canada and 11 percent for the United Kingdom. In less developed countries, such as India and the Philippines, at home food expenditures often account for more than 50 percent of a household's budget. In India, the percent total personal consumption expenditures spent on food consumed at home is 51.3%.

Consumption trends change over the years, and this influences what the food industry does. However, demand for individual foods is more responsive to prices as consumers substitute among alternative food commodities. Rising incomes increase expenditures on more expensive foods, as consumers demand more convenience and quality. Demographic factors, such as changes in household size and the age distribution of the population, can bring about changes in consumption.

Away-from-home meals and snacks now capture almost half (45 percent) of the U.S. food dollar. This is up from 34 percent in 1970. Fast food accounts for the largest and fastest rising share of sales in the food industry. Sales in fast-food industries now outpace the sales in full-service restaurants. People want quick and convenient meals. They do not want to spend to much time in preparing meals, travelling to pick up meals, or waiting for meals in a restaurant. Consumers want to combine mealtime with time engaged in other activities such as shopping, work, or travel. For example, McDonald's, Pizza hut, KFC, Burger King, Taco Bell, and others are now located in conversant outlets.

2.5 STATUS OF FOOD PROCESSING IN INDIA

India is the world's second largest producer of fruits & vegetables, but hardly 2% of the produce is processed. India is the land of spices producing all varieties worth over Rs. 3500 crores (US $ 900 million) amounting to 25-30% of world production, which is processed for value-addition and export. It grows 22 million tonnes of oilseeds covering most of the varieties. Other important plantation products include tea, coffee, cocoa and cashew.

India's livestock population is largest in the world with 50% of world's buffaloes and 20% of cattle, but only about 1% of total meat production is converted to value added products. India is the largest milk producer in the world but only about 15% of the total milk production is processed through the organized sector. Size of the semi-processed and ready to eat packaged food industry is over Rs. 4000 crores (US $ 1 billion) and is growing at over 20%.

India has become a surplus producer of food from being an importer of food grains. However, India does not figure significantly in the world trade of food and food products. Food processing industry in India has been stagnant for a long time, although consumers in India spend more than half their expendable income on food, beverages and tobacco totalling almost Rs. 4000 billion.

There are a large number of small and medium size processing units and only a few large process houses. There are more than 800 flour mills, almost 600 fish processing units with about 4500 cold storages, over 5000 fruit and vegetable processing units, 170 meat processing units, about 650 soft drink units, more than 400 sugar mills and 700 solvent extraction units. With bigger units run by multi national companies, the number may not change significantly but there might be a qualitative change in the character of the industry.

Processed food industry ranks 5^{th} in size in India accounting for about 5.5% of GDP, employing more than 1.5 million workers in the industry with a size of about US$ 30 billion. More than 75% of the industry is in unorganized sector in terms of turnover with value added foods account for US$ 17 billion. The size of semi-processed and ready-to-eat/packaged food industry is about US$ 1 billion.

Processed foods worth over US$ 4 billion were exported in 2002-03, of which rice is about 46% and marine products about 34%. Major exports besides rice and fish products, have been fruits and vegetable products, meat and poultry products both fresh and frozen, egg products and tea. There are good prospects of having grains and grain products as well as milk and milk products also among the major export items.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. How the food industries are segmented?

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2. What is the status of food processing in India?

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2.6 MAJOR FOOD PROCESSING SECTORS THEIR STATUS, PROBLEMS AND PROSPECTS

Food processing industry in India can be segmented as follows:

1. Cereal/ pulse milling
2. Fruit & vegetable processing
3. Milk & milk products
4. Beverages like coffee, tea & cocoa
5. Fish, poultry, eggs & products
6. Meat & meat products
7. Aerated waters/soft drinks
8. Beer/alcoholic beverages
9. Bread, biscuits & other bakery products
10. Edible oil/fats.
11. Confectioneries
12. Breakfast cereals, malt protein, weaning, extruded food products

2.6.1 Problems in Food Processing Industries

At present most of the industries are in unorganized sectors. So, numbers of problems are arising from different sections of the industries. Some of the basic problems encountered by Indian food industries at different levels are given below.

Farm level problems

- Poor yield of farm produce and therefore low returns
- Lack of material resources necessary for development
- Primitive methods of farming
- No control on quality of inputs and lack of finance to manage.
- Vagaries of weather
- Unavailability of reliable handling and transportation system
- Lack of storage facilities at farm

Distributors problems

- Lack of modern transportation facilities and high cost
- Inadequate cold storage faculties
- Irregular quality of farm produce

Processing industries problem

- Financing
- Higher import duties
- Higher cost of raw material and packaging
- Inadequate transport and cold storage facilities
- Infrequent availability of refrigerated containers
- Staggering advertising costs
- Limited domestic market

Consumer discontent

- Does not get value for money
- The price variation is a day to day affair
- Continued dependence on seasonal products
- Lack of variety of semi processed or prepared convenience food at affordable prices.

The reasons for slow growth of processed foods in India in past are many. Majority of the population has low-income levels and cannot afford processed foods. Indians traditionally prefer fresh foods that are cooked rather than use preserved foods. There is also no national character for food habits and these keep changing from region to region. However, the scenario is changing with some foods especially the fast foods acquiring the national character. Also some foods such as idli, dosa, some Punjabi foods like chhole, alu mutter etc., some Chinese foods and now the western foods like burgers and pizza are fast gaining national popularity.

There are some factors that impede growth in this industry. Transport (both road and railways) and communication are poor. This causes special problems for perishable products. There are no reliable cold chains, which are necessary for temperature sensitive foods like fruits & vegetables, ice creams etc. Modernization is unaffordable for small-scale manufacturer but the large companies do not find investment justifiable due to small size of market. Packaging costs are high. Even the retail business in small stores so large that an inventory needed to display various brands and that is lacking. Supermarkets are not yet popular although a few are making appearance.

2.6.2 Prospects

Indian government is now making an effort to promote better growth of this industry by giving it a priority sector status for lending by banks, most of the industry (except in alcoholic beverages and those products reserved for small scale), have been exempted from licensing, have relaxation in small scale reservation, foreign technology agreements, agro-based export oriented units, assistance in research and development etc. Government is also trying to improve infrastructure support such as cold chain facilities, transport, storage warehouses, etc. Governments are setting up Food Parks, 10-year tax holiday, and replacement of PFA Act with a new more rational act. The bill for Integrated Food Law is likely to be introduced in the Parliament.

Because of liberalization and other developmental measures being taken, future of the industry looks very bright. To some extent cold chain is being provided, which will help in retaining quality, freshness and reduce post-harvest losses. With the new hybrid varieties being added the production season is also being extended. These developments shall result in the greater availability of quality raw materials to the industry thus resulting in better capacity utilization and producing a wider range of products and of international quality. The quality is now the watchword for success. The multinationals now entering the food industry have an international marketing network and have their brand loyalties all over the world. This will enable the Indian products reaching all over the world in the form and packing required.

With the rise in the per capita income particularly of the middle classes a drastic change in the food habits has been noticed. This will lead to an increased domestic consumption of processed foodstuffs.

2.7 CEREAL PROCESSING

India produces about 200 million tonnes of different food grains every year. All major grains like paddy, wheat, maize, barley, and millets like jowar (great millet), bajra (pearl millet) & ragi (finger millet) are produced in the country.

The country is self sufficient in grain production and is the second largest wheat and rice producer in world, with a 20% share in total world production.

Primary milling of rice, wheat and pulses is the most important activity in food grains. There are over 91,000 rice hullers and 2,60,000 small flourmills engaged in primary milling. Further there are about 43,000 modernized rice mills/huller-cum sheller and the quantity of rice bran processed for bran-oil extraction stood at 3.4 million tonnes in 1999-2000.

Around 820 large flourmills in the country convert about 10.5 million tonnes of wheat into wheat products. Branded rice is becoming popular in the country and significant corporate presence is there in the domestic as well as export markets. Some quantity of wheat and wheat products is also exported.

The total market of bakery product, bread and biscuit is 1.5 million tonne and 1.1 million tonne respectively in year 1998. The cake market alone is estimated at 0.4 million tonne. The organized segment of the biscuit market is estimated to be 0.44 million tonnes whereas the unorganized sector accounts for the balance 0.66 million tonnes. Bread market is estimated to be growing at around 7% per annum in volume terms, whereas the biscuit market in the recent years has witnessed a little higher growth at around 8-10% per year.

Besides the industrial areas in leading metropolis, the bakery products and confectionery are carried on small-scale basis also at household level. Whereas, the confectionery industry has developed remarkably with the international brands mingling with the domestic market toffees, chocolates etc. produced at large scale in important industrial regions of the country. During the last 2 decades, small and unorganized players shared the growth in the industry. Currently, there are an estimated 2 million bakeries across the country engaged in production of bread, biscuits and other products. The estimated annual production of bakery products in India is in excess of 3 million tonnes, of which bread accounts for nearly 50% and biscuits 37% in volume terms in the organized sector. Sugar-boiled confectionery, consisting of hard-boiled candy, toffees and other sugar-based candies, is the largest confectionary segments and valued at around Rs 2,000 crore. The confectionery industry has a current capacity of 85,000 tons; the market is growing at the rate of 10-15% per annum.

2.8 PULSE PROCESSING

In India, around 75% of pulses produced is consumed after having been milled for removal of the husk and splitting or after some processing. Losses take place at various stages after harvest viz. during storage, loosening of husk, at the time of processing, etc. Among post harvest operations, storage causes the maximum loss of 7.5%, processing, threshing and transport causes 1%, 0.5% losses respectively, aggregating 9.5% total loss. Though the main cause of low per capita availability is considered to be poor productivity and production but reduction in post harvest losses can enhance the availability to a considerable extent. However, most of the commercial technologies available for this purpose are either obsolete or inadequate and result in heavy losses due to breakage and powdering of the grain. Successful efforts have been made to develop improved technologies to reduce milling losses and improve product quality. Similarly there is a need for development and utilization of improved technologies for the manufacture of products based on grain legumes.

Conversion of pulses to dhal is the third largest food processing industry in the country after rice and wheat milling industries. It is estimated that about 75% of the pulses produced in the country are converted to dhal. Milling of pulses has been practiced as a small-scale rural operation from time immemorial and more recently as large commercial operation. About 30% of the production of pulses is retained by the farmers and is processed in rural sector using traditional techniques. Presently the dhal available in the market comes almost entirely from the large-scale mills. There are about 10,000 dhal mills working in various parts of the country processing different pulses throughout the year.

A majority of the 5500 mills, reported in the country are big and semi-automatic/ automatic. They process more than 80% of the pulses produced in the country. However, there is a good scope for new entrants in this field is of particular significance as pulses are the main suppliers of proteins and nutritious food to the poor masses.

Depending upon the scope for processing pulses, dhal-milling plants can be setup in rural areas so that the waste material available from this industry could be beneficially used for cattle feed and other purposes.

Many pulse milling machines, technology and process have been developed by different research organizations of the country to overcome most of the anomalies of the traditional methods. Some of these methods have better milling efficiency, more yield in lesser time and at lesser processing costs compared to the traditional process.

2.9 OILSEED PROCESSING

The vegetable oil processing and extraction industry also plays a vital role in our edible oil economy. It comprises the orthodox bullock driven crushers and the modern expander/extruder units. In recent times the processing sector has passed through a transitional phase, attempting to cope with the rapidly changing processing methods the world over.

Over the years the demand for both edible and inedible oils in India has been on the rise. The gap between demand and supply has been largely bridged by using innovative technologies and unconventional oil sources from forest based oilseeds. In recent years per capita consumption of edible oil has also been rising. It was estimated that edible oil demand would be about 7.1 million tonnes or 26 million tonnes of oilseeds. Although India produces about 7 million tones of edible oils annually, a gap may still arise as the industry sources are expecting an increase in our annual per capita consumption of edible oil to 9 kg. The domestic demand for edible oils has been growing at about 6.7 percent per annum whereas production only at 4.5 percent per annum.

The processing by the solvent extraction industry declined to 10.4 million tonnes in 1996 compared to 11.2 million tonnes in the previous year. Exports of oil meal, oilseeds and minor oils have reached 4.55 million tones) valued at Rs. 3766 crores ($ 1067 million) during the year 1996-97 at against 4.54 million tonnes (valued at Rs. 2873 crore equivalent to $ 820 million) in 1995-96, i.e. a quantum jump of 35 per cent over the previous year.

India has about 2.5 lakhs ghanis and kolhus and around 50.000 oil mills of different capacities. While most of the former categories have low productivity, majority of the oil mills have only the capacity of 1 to 5 tonnes per day and about 150 are having that of 50 tonnes per day.

Vanaspati production has been growing at an annual rate of 1.6 per cent during 1990-91 to 1995-96. Yet of its 161 units, 49 have put down the shutter during 1996. The vanaspati producer's are pressing for decontrolling the use of mustard oil in vanaspati production. Now the Vegetable Oils Products (VOP) industry is permitted to use only certain specified varieties of mustard. High input cost is a major constraint faced by the manufacturers. The vanaspati industry's capacity utilization went down to 36 per cent in 1994-95 from a high of 66 per cent in 1987-88. The industry has also added substantial capacities is complete disregard to the market demand, 26.6 lakh tones in 1994-95 compared to 15 lakh tones in 1986-87.

For increasing domestic production potential for vegetable oil (edible & industrial) from non-conventional sources, and integrated approach is necessary for exploitation of non-traditional oilseeds. Soybean and oil palm are two promising oil bearing materials for achieving self-sufficiency for India.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the major problems and prospects of processing industries?

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2. What is the status of grain and oilseed milling in India?

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2.10 HORTICULTURAL CROP PROCESSING

The commercial processing of fruit & vegetables is less than 2%. The main reason being that domestic consumption of processed items is quite meagre because of economic reasons and also as a matter of habit as consumers prefer fresh fruits & vegetables. The high cost of packaging pushes up the cost of the processed items and thereby makes them out of reach of the common man. Because of the varied agro-climatic conditions some fresh fruit & vegetable are available throughout the year.

Presently there are a little over 5198 units registered under the FPO distributed all over the country. Most of the units fall in the cottage and or small-scale sector. A few modern processing plants have, now come up and many more are in the pipeline. The installed capacity, which was 11.08 lakh tonnes, in 1993, increased to 21.00 lakh tonnes at the end of the year 1999. After the liberalization of the economic policies in the country, a few very modern plants produce mango pulp, tomato paste etc. in aseptic packing, freeze drying of many fruit & vegetables including mushroom is being taken up. It is expected that in the years to come, many modern state of the art plants shall come up.

The important items manufactured in the country are fruit pulps particularly of tomatoes & mangoes, ready to serve juices, canned fruits, jam, pickles, squashes, etc. Recently, items like frozen fruits, pulps, dehydrated & freeze-dried vegetables, canned mushrooms etc. are also being produced. In the coming years, new industries like carbonated fruit drinks, dehydrated and freeze dried fruits, fruit juice concentrates are expected to come up.

India in a small way has been in the export market for almost 30 years. Among the popular items in export are mango chutneys, pickles. Fruit juices, canned and dehydrated mushrooms, frozen & canned fruit & vegetables. In the year 1997-98 the exports of processed fruit and vegetables were in the order of 299 thousand tonnes valued at Rs. 761 crores (US $ 200 million).

Due to the WTO Agreement, all the exporting units will have to follow the Codex Alimentarius standards. This makes the compliance easier as one does not have to try to comply with several different legal requirements of different countries. There are many processors who export their products to several countries. Codex Alimentarius also has another requirement and that is Hazard Analysis and Critical Control Points (HACCP). This has been incorporated to ensure safety of food products. Although this is new to most Indian manufacturers, several processing units have already incorporated these requirements in their units.

The future looks quite promising for food processing industry. It is bound to grow at much more healthy rate as many plans are implemented. Government has a big role to play in its development and has already given its willingness to help the industry.

2.11 LIVESTOCK AND AQUACULTURAL PRODUCE PROCESSING

2.11.1 Fish Processing

With over 8000 km. of coastline, 3 million hectares of reservoirs and 1.4 million hectares of brackish water, India has vast potential for fishes from both inland and marine resources. Units mostly exist in the small-scale sector as proprietary or partnership firms or fishermen co-operatives. Over the last decade, the organized corporate sector has become increasingly involved in preservation, processing and export of coastal fish. But the wide variety of fish resources found in Indian inland waters, coastal areas and deep seas comprising India's Exclusive Economic Zone, still remain grossly under utilized

Processing of produce into canned and frozen forms is carried out almost entirely for the export market. In all, there are about 393 freezing units, 13 canning units, 160 ice-making units, 12 fishmeal units and also about 476 cold storage units. Processed fish products for export include: conventional block frozen products, individual quick frozen products (IQF), minced fish products like fish sausage, cakes, cutlets, pastes, surimi, texturised products and dry fish etc.

2.11.2 Meat Processing

India has a livestock population of 470 million that includes 205 million cattle and 90 million buffaloes. The country produces about 450 million broilers and 30 billion eggs annually. Animals, which are generally used for production of meat, are cattle, buffalos, sheep and goat, pigs and poultry. Mithun is also slaughtered for meat in North East and Sikkim. Rabbit meat is also used as a specialty in Kerala and some other states.

Consumption per head of both fresh and processed meat in India is very low at 1.5 kilograms. This compares with the world average of 35.5 kilograms. The production of meat and meat products has shown an impressive growth. The details of production of meat and meat products from 1994 to 1998 are as given Table 2.2.

Table 2.2: Production of meat and meat products (in thousand tonnes)

S. No	Meat product	1994	1995	1996	1997	1998
1.	Mutton and Goat Meat	637	647	669	670	675
2.	Pork Meat	366	420	420	420	420
3.	Poultry Meat	422	578	480	580	600
4.	Cattle Meat (Beef)	1290	1292	1202	1292	1295
5.	Buffalo Meat	1200	1204	1204	1205	1210

The total meat production in the country is 4 million tonnes, which includes beef, buffalo meat, mutton, goat meat, pork and poultry meat. However, only about 1% of the total meat is converted into value added products like sausages, ham, bacon, luncheon meat, kebabs, meatballs etc. The total meat export during 1999-2000 was Rs.845.00 crores consisting mostly of mutton and buffalo meat out of which 70% was contributed by export of buffalo meat.

The country has 3600 slaughterhouses, 9 modern abattoirs and 171 meat-processing units licensed under MPO. A few modern pork-processing plants are also coming up in the country. These are primary meat processing houses and are administered by local authorities. Most of them are outdated and use primitive technologies for the production of meat. There are very few modern facilities, although a few such units do exist for pork and bacon processing, for the integrated slaughter and processing of buffalo, sheep and goat meat and for the processing of poultry meat. In addition to this, a large proportion of meat production is slaughtered in houses or small-unlicensed establishments.

Poultry processing is still in its infancy. There are only seven modern integrated poultry processing plants. However, there are a good number of small poultry processing units engaged in production of poultry meat products. There are five egg-processing units engaged in exporting egg products.

The level of processing in the Indian market is very small and the potential for rapid growth is therefore substantial. With the advent of fast food outlets in all the metropolitan centers, the impact on meat processing industry is immense. As per capita incomes rises and urban families live in smaller units, the demand for processed meat products, which can be rapidly cooked, will rise.

2.12 NATIONAL FOOD PROCESSING POLICY

The Government has come out with a draft national food processing policy with a vision to motivate farmers and food processors and to provide interactive coupling between technology, economy, environment and society for steady development of food processing activities to build up a substantial base for production of value added agro food products for domestic and export markets with a strong emphasis on food safety and quality enabling the farmers especially to realize direct benefits of new technology and marketing network and to ensure adequate availability of quality food products for the consumers at affordable prices.

The policy will seek to create an appropriate environment for the entrepreneurs to set up food processing industries through rationalization of tax structure, harmonization & simplification of food laws, promotion campaign to create market for processed foods by providing financial assistance to Industry Associations, NGOs/cooperatives, private sector units, State Government organizations. It also includes infrastructural development programs like establishment of cold chain, low cost pre-cooling facilities near farms, cold stores and grading, sorting, packaging facilities, application of biotechnology, remote sensing technologies, energy saving technologies and technologies for environmental protection, building up a strong infrastructural base for production of value added products with special emphasis on food safety and quality matching international standards etc. The policy has many backward and forward linkages between farmers, market, processors and consumers.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the status and prospects of meat processing industries?

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2. What is National Food Processing Policy?

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2.13 LET US SUM UP

The food industry is divided into production manufacturing distribution and marketing. The industry is highly responsive to change and interrelated with others. Consumers drive the food industry and to some extent the food industry drives the consumer, making changes in food consumption, types and meals. Food is now a global commodity with changing tread scenario in the world.

The food processing industry in India is in its growing stage. It contributes 5.5% of GDP. Most of the foods processing industries are in unorganized sector. There are number of problems which are responsible for slow growth of food Industry. But the prospects of food industry are very good, as changes in the food habits have been observed in the recent past.

Cereal processing is the major food-processing sector in India. Numbers of bakery products are also produced in the India and the market is growing fast rate 7.5% of pulses produced in India is processed for preparation of dall. There are about 5500 processing mills in India. There are about 2.5 lakh *ghanis* in India. Vanaspati production sector is slow. The commercial processing of fruits and vegetables is only 2% in India. There are 5198 food processing units which are registered under food product order.

In fish processing the organized sectors are now coming up. There are about 393 freezing units in the country. Meat is one of the important export commodity in food processing export sector. Only 0.2% of total meat production is further processed at commercial scale. The poultry processing is in the starting phase.

The government has come out with a draft national food processing policy with a vision to motivate and provide interactive compiling between all stakeholders. The policy will seek to create an appropriate environment for the entrepreneurs to set up food processing industries through creating enabling environment, infrastructure development with backward and forward linkages.

2.14 KEY WORDS

National food processing policy : Draft of government on food processing policy of India.

Food processing industries	:	The industries engaged in commercial processing of foods.
Allied industries	:	The industries indirectly associated with food processing industries.
Cereal processing	:	The processing of cereals like wheat, paddy etc.
Primary processing	:	It includes cleaning/grading of raw material and dehusking.
Pulse processing	:	The processing of pulses to get the dall or any other product.
Oilseed processing	:	Processing of oilseeds to extract oil from oil-bearing seeds.
Horticultural crop Processing	:	Processing of fruits and vegetables to increase their shelf life and prepare other products.
HACCP	:	Hazard analysis and critical control points.
Fish processing	:	Processing of fish includes, freezing, canning, deboning etc.

Meat Processing: The processing of animal carcass for human consumption.

2.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include following points:

   - Classification based on units of industry
   - Classification on food products

2. Your answer should include following points:

   - Past and present status
   - Future prospects and scope

Check Your Progress Exercise 2

1. Your answer should include following points:

   - Problems of farmers, market, processor and consumers
   - Future scope, government policies

2. Your answer should include following points:

   - Cereal, pulses, oilseeds
   - Processing industries, potential

Check Your Progress Exercise 3

1. Your answer should include following points:

   - Meat, fish, poultry processing
   - Present status
   - Future scenario

2. Your answer should include following points:

   - Vision of policy
   - Linkages, creation of enabling environment, infrastructure

2.16 SOME USEFUL BOOKS

1. Economic Survey 2001-2002. Economic Division, Ministry of Finance, Government of India.

2. Fellows, P.J. (1998) Food Processing Technology, Principles and Practices. Woodhead Publishing Limited. Cambridge, England.

3. Parker, R. (2003) Introduction to Food Science. Thomson Learning Inc. New York.

4. Potter, N.N. and Hotchkiss, J.H. (1995) Food Science, 5th Edition. Chapman & Hall Publishing Inc, New York.

UNIT 3 FOOD LAWS AND ASSOCIATED BODIES

Structure

3.0 OBJECTIVES

After reading this unit, you should be able to:

- know types of standards;
- state prevention of food adulteration act (PFA), FPO & MPO, Bureau of Indian standards (BIS), AGMARK standards;
- learn international standards organization (ISO), AOAC, USDA and FDA
- explain codex Alimentarius, HACCP, GMP;
- know about different export promotion councils, APEDA, MPEDA;
- know the organisations - NABL, MFPI, FRAC; and
- organisation describe total quality management (TQM).

3.1 INTRODUCTION

Food processing involves number of unit operations and material handling. So, there are always chances that the food may be contaminated. The food material should also contain essential nutrients. So, standards are formed and number of agencies and organizations are involved at national and international level to make the standards implement and regulate them. This unit covers Indian and international standards and implementing agencies, export promotion agencies of India, NABL, etc. The quality assurance systems like HACCP, TQM and GMP are also covered in brief.

3.2 FOOD LAWS AND STANDARDS

Food is the basic need of all living organisms. Hence, its quality should be given top priority. Processing of the food and food products is usually done at mass scale. So, there are always the possibilities of food being adulterated. The contamination of food can affect a large number of populations at a time and hazards may occur. Secondly, the consumer must get the product for which he has paid. An article of food is called adulterated if the food contains any other substance which effects, or it so processed as to affect injuriously the nature, substance or quality, inferior or cheaper substance has been substituted, prepared and packed or kept under unsanitary condition whereby it has become contaminated or injurious to health, contains filthy, putrid rotten, decomposed or diseased animal or vegetable substance or is insect infested or is otherwise unfit for human consumption etc. The processors may add any prohibited preservative or permitted preservative in excess of the prescribed limits. So, it is essential to set the minimum quantities of desirable characteristics required and the maximum quantities of undesirable components that the food should contain. This also helps to set common standards for commodities and prevents confusion among consumers. Thus, the standards are formulated. There are several ways of arriving at the standards for product quality but four methods are commonly used;

1. **Legal standards:** Standards, which are established by government bodies.
2. **Company or voluntary standards:** Set by the various segments of food industry. Voluntary standards generally represent a consumer image and may become a trademark of product quality.
3. **Industry standards:** An organized group attempts to establish given limits of quality for any food product. Normally these become effective by pressure from marketing organizations or by specific commodity groups where legal standards are not involved.
4. **Consumer or grade standards:** The consumer standards represent the consumer requirements of a product and are generally based on experience of the industry with its consumer.

Out of these, the legal standards are the most important. In fact the government has empowered several agencies and promulgated a number of acts and orders to contract the menace. Agencies and institutions have also been created to lay down standards for the quality of foods. The manner in which the food is processed and packaged is also covered by a number of regulations. Many different types of standards apply to the evaluation, production, testing, and monitoring of dietary supplements. Regulations and product standards are used, as the "yardsticks" that define specific requirements manufacturers must follow to assure product safety and to provide accurate information to health professionals and consumers. These standards also encourage the safety and quality of products by manufacturer making sure that the product meets the standards.

3.3 INDIAN STANDARDS

The Government of India is fully aware of the possibilities of food being adulterated. It has therefore, several agencies, acts, standards and orders which have been formed to formulate standards, implement them, check the adulteration and protect the consumers. Some agencies and institutions were created to lay down standards for the quality of foods. The main agencies involved in this are described below.

3.3.1 Prevention of Food Adulteration Act (PFA)

One of the early acts to be promulgated in food laws and standards was the Prevention of Food Adulteration Act of 1954, which has been in force since June 1,1955, amended 1964 and again in 1976. The objective of this act was to ensure that food articles sold to the customers are pure and wholesome. It is also intended to prevent fraud or deception and encourages fair trade practices.

The Act prohibits the manufacture, sale and distribution of not only adulterated foods but also foods contaminated with toxicants and misbranded foods. A central committee for food standards has been constituted under the Act and has been charged with the function of advising the Central Government on matters relating to the Food standards.

The Food Health Authority is appointed at state level who is the Director of Public Health and Preventive Medicine. He is responsible for the good quality and standards of foods available to the consumers. Under FHA are the Local Health Authority (LHA). There is a Local Health Authority appointed in each city in every state.

3.3.2 Fruit Products Order (FPO)

The Government of India promulgated a Fruit Products order in 1946. In 1955, the order was revised. The Fruit Products Order (FPO) lays down statutory minimum standards in respect of the quality of various fruits and vegetable products and processing facilities. The FPO is enforced by the Department of Health. Presently there is a little over 5198 units registered under the Fruit Products Order of 1955 distributed all over the country. Most of the units fall in the cottage or small-scale sector. A few modern processing plants have, now come up and many more are in the pipeline. The installed capacity which was 11.08 lakh tonnes, in 1993 increased to 21.00 lakh tonnes at the end of the year 1999.

3.3.3 Meat Products Order (MPO)

It provides means to:

1. Detect and destroy meat of diseased animals.
2. Ensure that the preparation and handling of meat and meat products be conducted in a clean and sanitary manner.

3. Prevent the use of harmful substances in meat foods.

4. See that every cut piece of meat is inspected before sale to ensure its wholesomeness.

The order also lays down rules and conditions for the procedure to be adopted for the selection of disease-free animals, slaughterhouse practices.

3.3.4 Bureau of Indian Standards (BIS)

Bureau of Indian Standards (BIS) is the National Standards Organization established as a Society in 1947 as Indian Standards Institution and subsequently made a statutory body as BIS under Bureau of Indian Standards Act 1986. The Bureau comprises of members representing industry, consumer organizations, scientific and research institutions, professional/technical institutes, central ministries, State Government and Members of Parliament. The functions of Bureau are;

1. Standard Formulation.

2. Certification: Product, Quality Management System, Eco Mark, Environment Management System, Hallmarking of Gold Jewellery, Hazard Analysis and Critical Control Points.

3. Laboratory: Testing, Calibration and Management.

4. Standards Promotion.

5. Consumer Affairs.

6. Awareness and Training Programs.

There are 14 Technical departments engaged in formulation of Standards. So far 17000 Standards have been formulated in different technological areas depending upon the National priority. These standards are evolved through the consensus from sectors such as industry, Consumers, testing and laboratory experts and Government organization by co-opting them in the related technical committees, sub committee and panels. The standards are reviewed time-to-time and continuously updated to match the technological changes taking place. The BIS has formulated 1133 standards which pertains to food products.

3.3.5 AGMARK Standard

The AGMARK standard was set up by the Directorate of Marketing and Inspection of the Government of India by introducing an Agricultural Produce Act in 1937. The word 'AGMARK' seal ensures quality and purity. The quality of a product is determined with reference to the size, variety, weight, colour, moisture, fat content and other factors are taken into account. It covers the following commodities:

- Pulses
- Cereals, 1966, 2001
- Makhana
- Vegetable oils
- Fruits and vegetables
- Roasted Bengal gram
- Vermicelli, Macroni and Spaghetti

The grades incorporated are grades 1,2,3 and 4 or special, good, fair and ordinary. Any officer of the Central Government or a State Government, or any authority, authorized by the Central Government, may, if he has reason to believe that any provision of this Act or the rules made there under has been, or is being, contravened, enter any premises at any reasonable time and make necessary inspection of, and search for, the agricultural produce in relation which such contravention has been, or is being made. The officer can seize and penalize the firm for not meeting the standards. The Central Government can declare that the provisions of this Act shall apply to an article of agricultural produce not included in the schedule or to an article other than an article of agricultural produce and on the publication of such notification, such article shall be deemed to be included in the schedule.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand by standards and how they are arrived?

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2. What are the functions of BIS? How standards are formulated?

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3.4 INTERNATIONAL STANDARDS

Quality of food is major concern worldwide. So, each country has formulated its own standards and created agencies for strict quality control measures of the food products. Some of them are internationally accepted as standards. A brief description of some these standards are given in this section.

3.4.1 Association of Official Agricultural Chemists (AOAC)

AOAC is an independent association devoted to promoting methods validation and quality measurements in the analytical sciences. It does this by reviewing and validating approved standard methods of analysis. Promoting uniformity and reliability in statements of results, and developing and promoting criteria useful for laboratory accreditation and analysis certification.

AOAC official methods program is designed to provide methods of analysis for which performance characteristics have been determined and tested. The cornerstone of this program is the inter-laboratory collaborative study by which proposed methods are validated through independent testing in separate laboratories following the same method and analyzing the same samples. The methods can be used to determine compliance with government regulations, to maintain quality control and process requirements, to set and evaluate compliance with terms of procurement contracts, to conduct national and international trade and to support research.

The AOAC methods are recognized worldwide as an authoritative resource, because of thorough and rigorous testing characterization. They are written in U.S. Code of Federal Regulations, Product specifications, and product acceptance, relied on legal proceedings, and required as a basis of national and international trade. They are also adopted by other national and international standards organizations.

3.4.2 United States Department of Agriculture (USDA)

It is the main body of food standards in USA. Regulations and directives are developed by USDA to ensure compliance with all relevant federal laws of USA, executive orders, directives, and policies. It provides links to key Federal Regulations and public laws enacted for USDA food distribution commodity programs and food purchase programs. Regulations and policies of USDA govern food safety related programs, processed product directives, the import and export of meat, poultry, and egg products, and laboratory services. It manages the process of developing food and nutrition regulations and ensures that all the relevant food and nutrition agencies participate in this development process. These regulations provide official marketing standards for grains and oilseeds, and require that exported grains and oilseeds be officially weighed and inspected. The Department's laws also regulate the slaughter and manufacture of meat products. The regulations also protect and promote U.S. agricultural health, administer the Animal Welfare Act, carry out wildlife damage management activities, and ensure that America's agricultural exports are protected from unjustified trade restrictions.

3.4.3 Food and Drugs Administration (FDA)

The Food and Drug Administration of USA is one of the oldest and most respected consumer protection agencies. Its mission is to promote and protect the public health by helping safe and effective products reach the market in a timely way, to monitor products for continued safety after they are in use, and to help the public get the accurate, science-based information needed to improve health. FDA’s regulatory approaches are as varied as the products it regulates products such as new drugs and complex medical devices, other products such as x-ray machines and microwave ovens, cosmetics and dietary supplements that must be proven safe and effective before companies can put them in the market. FDA safeguards the USA food supply by making sure that all ingredients used in foods are safe, and that food is free of contaminants like disease-causing organisms, chemicals, or other harmful substances. The agency must approve new food additives before they can be used in foods. It also monitors the safety of dietary supplements and the content of infant formulas and medical foods. FDA regulates all medical devices, including simple items like thermometers to very complex technologies such as heart pacemakers and dialysis machines. However, only the most complex new medical devices are reviewed by the agency before marketing.

3.4.4 International Standards Organization (ISO)

ISO prepared a document called ISO 9000 series in 1987 (modified in 1994) as a guideline for all organizations on managing quality and standard. Its Indian equivalent is IS 14000 (1988). It is the principle and criteria for a management system, which will improve a company's performance. It is a media for ensuring orderly and systematic maintenance and upkeep of system. It covers quality, quality policy, quality management, quality system, quality control, quality assurance, quality improvement, product, service, process and customer. The ISO series is given below;

ISO 9000-1,2,3,4	:	Quality management and quality assurance
ISO9004-1:		Quality management and quality system elements subcontractor
ISO9004-2:		Guidelines for services
ISO9004-3:		Guidelines for processed materials
ISO9004-4:		Guidelines for quality improvement
ISO9004-5:		Guidelines for project management
ISO9004-6:		Guidelines for quality plans
ISO9004-7:		Guidelines for configuration management
ISO 10011-1,2,3	:	Guidelines for auditing quality system
ISO 10012-1,2	:	Quality assurance requirements for measuring equipment
ISO 10013:		Guidelines for developing quality manual
ISO 10014:		Guidelines for economic effect of quality
ISO 10015:		Continuing education and training guidelines

3.4.5 Codex Alimentarius

The term Codex Alimentarius is taken from Latin and means food code. The FAO/WHO Codex Alimentarius Commission was established to implement the joint FAO/WHO Food Standard Program. About 150 countries including India are member of the commission. The purpose of this program is to protect the health of consumers and to ensure fair practice in the food trade; to promote coordination of all food standards work undertaken by international governmental and non-governmental organizations; to determine priorities and initiate and guide the preparation of draft standards through and with the aid of appropriate organizations; to finalize standards and after acceptance by Governments, publish them in a Codex Alimentarius either regional or worldwide standards. It brings together all the interested parties -scientists, technical experts, governments, consumers and industry representatives to help develop standards for food manufacturing and trade. These standards, guidelines and recommendations are recognized worldwide for their vital role in protecting the consumer and facilitating international trade. As Codex Alimentarius represent a consensus of food and trade experts from around the world, these standards are more and more being used in international trade negotiations and also for setting of disputes by WTO.

The Codex contract Point in India is the Directorate General of Health Services (DGHS) in the Ministry of Health. Ministry of Food processing Industries is also closely associated with the activities of Codex Alimentarius.

3.4.6 Hazard Analysis and Critical Contort Point (HACCP)

Hazard Analysis and Critical Control Point (HACCP) is an important quality assurance system. This system ensures that the products are safe and have good quality. The system is extremely desirable in view of the changing scenario in the International trade. It is science based and systematic, identifies specific hazards and measures for their control to ensure the safety of food. HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end product testing. The system is capable of accommodating changes such as advances in equipment design, processing procedures or technological developments. It can be applied throughout the food chain from primary production to final consumption and its implementation should be guided by scientific evidence of risk to human health. The application of HACCP is compatible with the implementation of quality management systems, such as ISO 9000 series and is the system of choice in the management of food safety within such systems. The HACCP system consists of following seven principles;

1. Conduct a hazard analysis.
2. Determine the Critical Control Points (CCPs).
3. Establish critical limits.
4. Establish a system to monitor control of CCP.
5. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
6. Establish procedures for verification to confirm the HACCP system is working effectively.
7. Establish documentation concerning all procedures and records appropriate to these principles and their application.

Prior to application of HACCP to any sector of food chain, the sector should be operating according to Codex General Principles of Food Hygiene, the appropriate Codex Codes of Practice, and appropriate food safety legislation. During hazard identification, evaluation and subsequent operations in designing and applying HACCP systems, consideration must be given to the impact of raw materials, ingredients, food manufacturing practices, role of manufacturing processes to control hazards, likely end use of the product, categories of consumers of concern and epidemiological evidence relative to food safety. The application of HACCP principles consists of following tasks;

1. Assemble HACCP team. The team must comprise of all experts required for the development of an effective HACCP plan for a specific food commodity.
2. All the information of the product such as composition, physical/ chemical structure treatments etc should be described.
3. The intended use should be identified. It should be based on uses of the product by the end user or customer.

4. The HACCP team should construct a flow diagram covering all the steps in the operation.

5. On-site confirmation of the flow diagram should be done and amendments in the flow diagram should be done if required.

6. All the hazards associated with each step should be listed, a hazard analysis should be conducted and controls measures should be considered for identified hazards.

In a large food factory the team should be multi-disciplinary that is, it should include a microbiologist, processing specialist, chemist, biochemist, engineer, packaging technologist, sales and training staff and personnel managers. For medium and small scale, the quality control and production managers and few supporting staff like sales and administrative managers should be enough.

3.4.7 Good Manufacturing Practices (GMP)

GMP provides quality assurances that off-the-shelf testing cannot. It provides continual measures of quality that can uncover problems and fluctuations as they occur before the product is shipped. The need for GMP takes on further importance because the issues involved in developing test methods for dietary supplements are many and complex. Until methods are further developed, standardized, and widely accepted, GMP serves as a primary vehicle for ensuring quality.

Good manufacturing practices (GMP) lie at the heart of quality. GMP comprise a variety of practices that ensure quality including things such as:

- Raw materials quality assurance
- Record-keeping of substances throughout the manufacturing process
- Standards for cleanliness and safety
- Qualifications of manufacturing personnel
- In-house testing
- Production and process controls
- Warehousing and distribution

Virtually every manufacturer adheres to an in-house GMP standard, which varies from producer to producer. In-house GMP, while often extremely effective, does not provide a means for outside verification of quality. In order to provide such verification, many are now embracing to industry-standard GMP that is usually subject to an independent outside audit for compliance.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate AOAC, USDA and FDA.

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2. What do you understand by HACCP? How quality assurance is achieved through it?

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3.5 EXPORT PROMOTION COUNCIL

The Export Promotion Council has been constituted to check the quality of a number of food materials meant for export. The council has powers to reject any food item, which does not measure up to the standards prescribed for the food. Federation of Indian Export Organizations (FIEO) is the apex body of all Export promotion councils/Commodity Boards/Export Development Authorities in India. There are 25 boards and export development authorities. The main work of these authorities is to promote the export, assure the quality of the product the international standards, formulate the standards for export etc. List of export councils related to food products are given below.

1. Agricultural and Processed Food Products Export Development Authority (APEDA)
2. Cashew Export Promotion Council of India
3. Coffee Board
4. Marine Products Export Development Authority (MPEDA)
5. Shellac Export Promotion Council
6. Spices Board
7. Tea Board
8. Tobacco Board
9. Wool and Woollen Export Promotion Council

3.6 APEDA AND MPEDA

3.6.1 Agricultural and Processed Food Products Export Development Authority (APEDA)

APEDA is an autonomous organization attached to the Ministry of Commerce of the Government of India. The main function of APEDA is to build links between Indian producers and the global markets. APEDA undertakes the briefing of potential sources on government policy and producers along with providing referral services and suggesting suitable partners for joint ventures besides arranging buyer-seller meets. It also provides recommendations to the Trade and Industry.

APEDA offers financial assistance under various schemes, which seek to promote and develop agro exports. Financial assistance under these schemes is available to exporters, growers, and trade associations, governmental agencies.

3.6.2 Marine Products Export Development Authority (MPEDA)

The Marine Products Export Development Authority (MPEDA) was constituted in 1972 under the Marine Products Export Development Authority Act 1972. The role envisaged for the MPEDA under the statute is comprehensive covering fisheries of all kinds, increasing exports, specifying standards, processing, marketing, extension and training in various aspects of the industry.

MPEDA functions under the Ministry of Commerce, Government of India and acts as a coordinating agency with different Central and State Government establishments engaged in fishery production and allied activities. The plan schemes of the Authority are implemented under four major heads:

1. Export production - Capture Fisheries
2. Export production - Culture Fisheries
3. Induction of New Technology and Modernization of Processing Facilities.
4. Market Promotion

It implements developmental measures vital to the industry like distribution of insulated fish boxes, putting up fish landing platforms, improvement of peeling sheds, modernization of industry such as upgrading of plate freezers, installation of IQF machinery, generator sets, ice making machineries, quality control laboratory etc.

3.7 FOOD HEALTH AUTHORITY

The Food Health Authority is appointed at state level that is the Director of Public Health and Preventive Medicine. It is responsible for the good quality and standards of foods available to the consumers. Under FHA is the Local Health Authority (LHA). There is a Local Health Authority appointed in each city in every state. The food Inspector is appointed by the Central or State Government by notification in official gazette. The main work of this authority is to take a random sample of any food article from any person selling such article, or who is in the course of delivering or preparing to deliver such article to a purchaser or consignee or a consignee after delivering of any such article to him. Then these samples are sent for analysis to the Public Analyst (PA) of local area.

3.8 NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES (NABL)

The concept of Laboratory Accreditation was developed to provide a means for third-party certification of the competence of laboratories to perform specific type(s) of testing and calibration. Laboratory Accreditation provides formal recognition of competent laboratories, thus providing a ready means for customers to find reliable testing and calibration services in order to meet their demands. It enhances customer confidence in accepting testing / calibration reports issued by accredited laboratories.

National Accreditation Board for Testing and Calibration Laboratories (NABL) is an autonomous body under the aegis of Department of Science & Technology, Government of India, as a registered Society. NABL has been established with the objective to provide Government, Industry Associations and Industry with a scheme for third-party assessment of the quality and technical competence of testing and calibration laboratories. Government has authorized NABL as the sole accreditation body for Testing and Calibration of laboratories.

NABL provides laboratory accreditation services to laboratories that are performing tests / calibrations in accordance with ISO/IEC 17025. These services are offered in a non-discriminatory manner and are accessible to all testing and calibration laboratories in India and abroad, regardless of their ownership, legal status, size and degree of independence.

NABL has established its Accreditation System in accordance with ISO/IEC Guide. In addition NABL has to also comply with the requirements of APLAC MR001, which requires the applicant and the accredited laboratories to take part in recognized Proficiency Testing Programs in accordance with ISO/IEC Guides. NABL has been conducting Proficiency Testing with the help of selected accredited laboratories as nodal laboratories in different fields.

NABL accreditation is a formal recognition of the technical competence of a testing or calibration laboratory for a specific task following ISO/IEC 17025 Standard. This is based on third party assessment.

NABL Accreditation is currently given in the following fields:

Testing laboratories	Calibration Laboratories	Clinical Laboratories
• Biological • Chemical • Electrical • Electronics • Fluid-Flow • Mechanical • Non-Destructive • Photometry • Radiological • Thermal	• Electro-Technical • Mechanical • Fluid Flow • Thermal & Optical • Radiological	• Clinical Biochemistry • Clinical Pathology • Haematology • Microbiology and Serology • Histopathology • Cytopathology • Cytogenetics • Immunology • Nuclear Medicine • Blood bank and transfusion services

3.9 FOOD RESEARCH AND ANALYSIS CENTER (FRAC)

The Food Research and Action Centre (FRAC) is a leading national organization working to improve public policies to eradicate hunger and under-nutrition in the United States. Founded in 1970 as a public interest law firm, FRAC is a non-profit and non-partisan research and public policy centre that serves as the hub of an anti-hunger network of thousands of individuals and agencies across the country.

- FRAC engages in a variety of activities at the national, state and local levels to form a comprehensive strategy for reducing hunger in this country.

3.10 MINISTRY OF FOOD PROCESSING INDUSTRIES (MFPI)

The Ministry of Food Processing Industries, set up in July 1988, is the main central agency of the Government of India responsible for developing a strong and vibrant food processing sector; with a view to create increased job opportunities in rural areas, enable the farmers to reap benefit from modern technology, create surplus for exports and stimulating demand for processed food. The subjects looked after by the Ministry are:

- Fruits and vegetable processing industry
- Food grain milling industry
- Dairy products
- Processing of poultry and eggs, meat and meat products
- Fish processing
- Bread, oilseeds, meals (edible), breakfast foods, biscuits, confectionery (including cocoa processing and chocolate), malt extract, protein isolate, high protein food, weaning food and extruded/other ready to eat food products
- Beer, including non-alcoholic beer
- Alcoholic drinks from non-molasses base
- Aerated waters / soft drinks and other processed foods
- Specialized packaging for food processing industries

The scope of the Ministry has been very much enlarged. It includes development of fruit &. Vegetable processing and promote food-grain milling including dairy products and processing of poultry, eggs & meat products. Processing of fish including canning & freezing and technical assistance to the industry also form a very important part of its activity. In addition planning & developing of industries relating to bread, oilseeds, breakfast food, biscuits, confectionery specialized packaging, including non-alcoholic beer, aerated drinks also fall within the scope of this Ministry.

3.11 TOTAL QUALITY MANAGEMENT

Total Quality Management is a process, which explores the formation of management and employees into a "team-concept" approach to production of quality products. It is a structured system for satisfying internal and external customers and suppliers by integrating the business environment, continuous improvement, and breakthroughs with development, improvement, and maintenance cycles while changing organizational culture.

One of the keys that are most important to the successful implementation of Total Quality Management is the idea that it is a structured system. It is basically a strategy derived from internal and external customer and supplier wants and needs that have been determined through daily management. The implementation of Total Quality Management requires the help of the following eight key elements.

1. Ethics
2. Integrity
3. Trust
4. Training
5. Teamwork
6. Leadership
7. Communication
8. Recognition

Total Quality Management is built on a foundation of ethics, integrity and trust. It fosters openness, fairness and sincerity and allows involvement by everyone.

3.12 PRODUCT CERTIFICATE AND LICENSING

Product certification and licensing in India is done by number of organization. BIS operate product certification under the rules and regulation of BIS Act 1986. A manufacturer is granted license to use the standard mark after assessment of his infrastructure facilities for manufacturing and quality control checks to produce goods in consistent with quality control. The conformity to standard is further ensured by regular surveillance at licensee's performance by surprise inspections and testing of samples from the factory and market. BIS offers certification schemes to food industries on

1. Food safety certification against IS 15000:1998

2. HACCP based quality system certification for two certification

    a) Audit certification of quality system against IS/ISO 9000, and
    b) Certification of HACCP against IS 15000:1998.

The BIS has brought 1435 items and over 7500 factories under its fold. Items affecting health and safety of consumer have been enforced through compulsory certification. In 1991 Government of India introduced "ECO" mark for environmentally friendly products.

The Directorate of Marketing and Inspection (DMI) issues "AGMARK" certificate to the notified food products. It enforces the Agriculture Produce Grading and Marketing Act 1937. Grading under this provision is voluntary. It involves sorting of commodities according to their quality followed by inspection to verify the correctness of grade assigned to them. It is also enforcing MPO.

Ministry of Civil Supplies, Consumer Affairs and Public Distribution is responsible for standardization of weight and measures. They regulate the quality of the vanaspati vegetable oils and fats through solvent extraction plants. The new act contains provision for regulation to pre-packed commodities, which are intended to establish fair-trading and price discipline for commodities sold to consumers in packed form with levelling.

For export materials, APEDA issues the certificate. . The authority feels that the products complying with the basic quality and safety requirements should carry a mark that remains sacrosanct across categories and communicates the adherence to quality assurance measures. With this in view, a system for grant of the Certification mark i.e. "Quality Produce of India" has been developed by APEDA for agricultural products being exported. The Certification Mark will be granted on the basis of compliance with hygiene standards, implementation of Quality Assurance System such as ISO 9000, Food Safety System such as HACCP, backward linkage, residue testing of pesticides and contaminants, laboratory facilities and nature of complaint etc. Initially, the proposal is to launch this scheme for few products like meat, rice, fruits and vegetables. This Certification Mark is owned by APEDA. Only such exporters whose produce/ products conform to the prescribed parameters are allowed/ licensed to use the trademark for exports.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are APEDA and MPEDA and what are their functions?

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2. Why accreditation is required? Define the role of NABL.

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3. What do you understand with Total Quality Management?

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3.13 LET US SUM UP

Consumers expect certain qualities from their food. To arrive the quality character tics, different types of standards are made. Food science determines and uses methods to measure food quality factors. Number of agencies and organizations are involved at national and international level to make the standards implement and regulate them.

PFA is implemented in 1955 to ensure that food articles sold to the consumers are pure and wholesome. FPO and MPO were also enforced to lay down statutory minimum standard for fruits, vegetables and meat. BIS is a body responsible for laying down policy guidelines for formulating standards.

International agencies like AOAC are involved in promoting methods validation and quality measurement of food products. USDA and FDA are the agencies for formulating and implementing standards. ISO is the organization on managing quality and standards codex Alimentarius was established to implement the food standard programme into member countries in post WTO era. HACCP and GMP are quality assurance systems.

Different export promotion councils are constituted in India to promote export like APEDA, MPEDA etc. NABL was developed to provide means for ratification of the competence of laboratories to perform specific type of works. MFPI is the main control agency in India for food processing.

3.14 KEY WORDS

AOAC : Abbreviation for Association of official Analytical chemists.

Certificate : A document providing evidence of status of qualification.

Critical control point : Any point in the process where loss of control may result in a heath risk.

Food safety : A judgment of acceptability of the risk involved in eating a food; of risk is relatively low, a food substance may be considered.

GMP : Good manufacturing practices guidelines that a company uses to evaluate the design and constriction of food processing plants and equipment.

HACCP : Hazard Analysis Critical Control Point; a preventive food safety system.

Standards : Set up and established by authority as a rule for the measure of quantity, weight, extent, value, or quality. Set by different agencies to specifically describe a food; to be labelled as such, a food must meet these specifications.

TQM : Total quality management.

NABL : National Accreditation Board for Testing and Calibration Laboratories.

FRAC : Food Research and Analysis Centre, an organization to improve public polices in USA.

3.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include following points:

   - Definition
   - Legal, company, industry, and consumer standards

2. Your answer should include following points:

   - BIS
   - Function of BIS
   - Formulation process

Check Your Progress Exercise 2

1. Your answer should include following points:

   - Associations information, functions
   - Status and regulations

2. Your answer should include following points:

   - Quality assurance system, need
   - Principles, tasks

Check Your Progress Exercise 3

1. Your answer should include following points:

   - Purposes, structure
   - Functions

2. Your answer should include following points:

   - Concept of accreditation
   - Need, functions of NABL

3. Your answer should include following points:

   - Need, importance
   - Key elements

3.16 SOME USEFUL BOOKS

1. Fellows, P.J. (1998) Food Processing Technology, Principles and Practices. Woodhead Publishing Limited. Cambridge, England.

2. Parker, R. (2003) Introduction to Food Science. Thomson Learning Inc. New York.

3. Potter, N.N. and Hotchkiss, J.H. (1995) Food Science, 5th Edition. Chapman & Hall Publishing Inc, New York.

4. Potter, N.N. (1987) Food Science. S.K. Jain for CBS Publishers & Distributors, New Delhi.

UNIT 4 FOOD GRAINTS, PULSES AND OIL SEEDS

Structure

4.0 OBJECTIVES

After reading this unit, you should be able to:

- explain importance of cereals pulses and oil seeds in our day-to-day requirement and to national economy;
- state the important properties and primary processing methods to make them edible and their storage; and
- describe value added products and Utilization of by products of cereals, pulses and oilseeds.

4.1 INTRODUCTION

Food grains play a major role in the Indian economy as they meet our food and fiber requirements. Food grains are the basic need of day-to-day requirement of human life. With the increase in population and awareness, every human being need right quality of foodstuff at the right time. It is also our duty that the cost of the foodstuff to meet the basic need should be affordable to every one. Agricultural produce are seasonal, weather dependent thus their storage for whole year and some times more than a year is required. During the storage, the quality of the foodstuff should not deteriorate. Most of the agricultural produce (cereals, pulses and oil seeds) is not consumed as they are produced. These produce need to be processed. The processing should be economically viable and the loss of energy and nutrition should be the least. Therefore, knowledge of appropriate machines and process is must.

Food processing industries have enormous significance in the national development through linkage between two main pillars of economy namely industry and agriculture. Growth of food processing industry means raising agricultural yield and creating rural employment. It leads to rise in the economic standard of large number of people through out the country.

4.2 PRODUCTION AND IMPORTANCE

Agricultural production in India has travelled a long way in the post independent era from scarcity to surplus. After green revolution the country has become not only self-sufficient but also surplus in food grain production. Now the country is producing about 200 million tonnes of food grains (90 million tonnes of paddy, 75 million tonnes of wheat and other coarse grains) 15 million tonnes of pulses and 23 million tonnes of oil seeds. In spite of such huge production, our population have per capita availability is less than the dietary requirement given by Indian Council of Medical Research. Therefore, nation has to import edible oil from other countries.

Post harvest technology of food grains have also had a paradigm shift in the last 50 years. At the time of independence most of post harvest operations were carried out by small scale processing units. These units were operated by human or animal power. There recovery was less and losses were high. Now many modern processing units comprising primary to tertiary processing are working. These units not only process the material but also process the byproducts into value added products.

4.3 STRUCTURE AND COMPOSITION

Wheat is a single seeded fruit consisting germ and endosperm enclosed by epidermis and seed coat. Paddy, pulses and other crops consist an outer husk cover in addition to above parts. The husk consists of silica acts as a barrier to moisture migration, insect infestation and fungal damage.

The germ is the principal part of the seed. It is rich in fat and is heat sensitive. The endosperm is full of starch granules and works as reservoir of food for developing embryo.

The chemical composition of the seed is widely dependent upon the environment in which crop is produced, the variety, soil and fertilizer application. In general, cereals are rich in carbohydrate; pulses are in protein and oilseeds in fats and lipids. The proximate composition of important cereals, pulses and oilseeds are given in Table 4.1. In general outer layers (pericarp) contains cellulose, endosperm is rich in carbohydrate and small amount of proteins, germ contains the highest amount of fat, protein, enzyme and small amount of sugars.

Protein present in the cereals gets denatured above 50°C. Thus, their water absorbing and swelling capacity decreases. It affects the quality of dough. The starch is insoluble in cold water. Its quality is not affected even if the temperature is raised to 60°C. However, at temperature higher than 70°C geletinization of starch takes place. It leads to deterioration in the colour. Fats are heat resistant up to an extent. However, at higher temperature (above 70°C) partial decomposition starts and increases the acid numbers. Vitamins present in the germ are destroyed with the heat treatment.

4.4 POST HARVEST LOSSES

With the green revolution and support of farmers the country has increased its food grains production to four fold between 1950's and 1970's. Though the rate of increase in production has declined after 1980's but still it is more than our country's requirement. It is also estimated that about 8 to 12% of the produce is lost in various post harvest handling and storage practices. The loss amounts to be Rs. 20,000/- crores annually.

The traditional processing of dal and oilseeds results in poor recovery. In most of the pulse mills in India has the dal recovery of 65 to 70 % against maximum possible recovery of 81 to 84 %. Similarly oil remains in the residual oil cake which is about 10 to 15 % of total available oil in the oilseed.

The maximum loss of food grain occurs during storage. As you know, in India major portion of food grains (more than 75%) is stored in large number of small capacity rural godowns. These godowns have free access to insect-pest, rodents and also affect the quality of the grains by the change of environment. It is estimated that in some of the godowns the losses are as high as 30 % in humid region if grains are stored for 8-10 months.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name two main pillars of Indian economy.

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2. "Whole world is looking towards India as a big market". Give reasons?

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3. List the factors, which affects the chemical composition of the grains?

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4. What happen to the solubility of starch when temperature increases?

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5. Post harvest losses in the pulses are mainly during ………………………...

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Table 4.1: Average composition of food grains, pulses and oil seeds

Commodity	Moisture (%)	Calories (Cal/ 100g)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Mineral (%)	Thia-mine (mg/ 110g)	Ribo-flavin (mg/ 100g)	Niacin (mg/ 100g)
Wheat	12.5	330	12.3	1.8	2.3	1.7	1.5	0.52	0.12	4.3
Paddy	12.0	360	7.5	0.9	0.9	1.2	0.7	0.34	0.05	4.7
Corn	13.8	348	8.9	3.6	2.7	1.2	1.5	0.37	0.12	2.2
Bajra	12.4	360	9.5	5.0	1.2	2.5	2.7	0.73	0.38	2.3
Ragi	13.1	332	7.1	1.3	3.3	2.7	2.0	0.42	0.12	1.1
Bengalgram	9.8	361	17.1	5.3	3.9	-	2.7	0.45	0.21	2.6
Blackgram	10.9	350	24.0	1.4	-	-	3.4	0.45	0.22	2.0
Cowpea	12.0	327	24.6	0.7	3.8	-	3.2	0.50	0.21	1.5
Greengram	10.4	350	24.0	1.3	-	-	3.6	0..46	0.21	2.0
Soyabean	8.1	432	43.2	19.5	3.7	-	4.6	0.73	0.32	2.4
Mustard	7.9	549	26.7	40.1	4.1	-	1.9	0.90	0.13	14.1

Source: NIN, ICMR, Hyderabad 1999

4.5 PHYSICAL AND THERMAL PROPERTIES

The knowledge of properties of grains such as size, shape, surface area, different densities, colour, frictional properties, thermal properties, diffusivity, equilibrium moisture content etc. are important for designing the various post harvest handling, storage, separation and drying systems. Some of the properties are discussed hereunder in this unit.

- Physical properties
- Thermal properties

4.5.1 Physical Properties

Accurate measurement of size and shape of the individual grain are important engineering data. These data helps in designing of machines for the post harvest handling and processing. The size and shape of the grain helps in designing cleaner, grader and if grains are to be passed between two rollers for shelling, milling or crushing. The terminal velocity of the grain helps in designing pneumatic conveyor, winnower etc. The geometry of the grain provides the surface area, which helps in moisture migration (absorption or drying). In general three major axis are measured and denoted as dimension a, b and c of the grain. **The sphericity** is defined as the ratio of geometric mean of 3-major axis to the largest axis dimension. It represents degree of closeness of the grain with the sphere.

$$\text{Size of the grain} = (a \times b \times c)^{1/3}$$

$$\text{Sphericity of the grain} = (a\,b\,c\,)^{1/3} / a$$

Where, a: is the largest dimension of the grain.
b: is the medium dimension perpendicular to the largest dimension of the grain.
c: is the smallest dimension perpendicular to above two of the grain.

Some dimensions and sphericity of the grains is given in **Table 4.2**

Table 4.2: Major dimensions and sphericity of the grains

Grains	Longest dimension (a) (mm)	Medium dimension (b) (mm)	Smallest dimension (c) (mm)	Sphericity $\frac{(abc)^{1/3}}{a}$
Rice, IR-8	8.68	3.02	1.97	0.427
Wheat, PB593	6.43	3.55	3.09	0.652
Maize, Ganga 5	8.92	8.33	6.89	0.901
Bengal gram	8.56	6.25	5.96	0.801
Black gram	4.87	3.90	3.37	0.762
Green gram	3.86	3.18	3.11	0.865
Pea,VRS-6115	6.89	6.43	6.04	0.945
Pigeon pea	6.56	5.30	4.63	0.895
Groundnut kernel	14.45	8.74	7.50	0.685
Soya bean	7.02	6.29	5.05	0.874

Source: Engineering Properties of Food Materials (1980) CIAE, Publication /80/15

The bulk density, specific gravity and porosity plays an important role for designing the storage structures, specific gravity separator, pneumatic conveyor and other handling equipments. The bulk density is defined as the weight of grains per unit volume. The specific gravity is defined as the ratio of true density (mass of the grains per unit solid volume) to the density of water. The true density of the grains is calculated by fluid displacement method using **pycnometer.** The density of the grains varies with the variety and moisture content. The porosity is calculated from the true and bulk density of the grains. The porosity is affected by degree of compaction. Some properties of the grains are given in Table 3.

Angle of repose and frictional properties of grains plays an important role in designing hoppers, discharge chutes, elevators, dryers, storage bins and other equipments for grain flow and handling. The frictional coefficient depends upon the shape of the grain, surface characteristics and moisture content of the grains. **The angle of repose** of the grains is the angle between the base and the slope of the cone formed, when grains are freely dropped on the horizontal plane. The frictional properties and angle of repose of some grains are given in Table 4.3.

Table 4.3: Some physical and mechanical properties of the grains

Grains	Moisture content (%, wb)	Bulk Density (Kg/m^3)	True Density (Kg/m^3)	Porosity	Angle of repose (Degree)	Friction coefficient on sheet metal
Wheat	8-14	790-700	1390-1400	40	26-28	0.40
Rice	9-11	610-580	1200-1240	54	27-30	0.48
Corn	10	820	1393	41	26-28	0.23
Soya bean	10-11	680	1180	42	24-25	0.34
Pigeon pea	9-10	815	1330	39	19	0.29
Gram	8-9	815	1340	39	17	0.35

Source: Engg. properties of Food material (1980) CIAR Publication /80/15

4.5.2 Thermal Properties

Cereals, pulses and oilseeds are harvested at higher moisture content in order to reduce shattering losses and safety against untimely rains or weather. These grains are to be dried to safe moisture level for marketing, processing or storage. For that heating, drying and cooking may be involved. Therefore, thermal properties namely, conductivity, diffusivity etc are required to be known for designing the dryers, cookers etc. Thermal properties of some grains are given in Table 4.4.

Table 4.4: Thermal properties of grains

Grains	Moisture content (%, db)	Specific heat (KJ / Kg K)	Thermal conductivity (W / m K)	Thermal Diffusivity (10^{-7} m^2 /s)
Wheat	10-20	1.09	0.139	0.91
Rice	10-20	1.33	0.087	1.00
Corn	10-20	1.20	0.165	0.89
Pigeon pea	8-22	1.50	0.153	0.94
Soyabean	8-10	2.01	0.116	0.54
Bengal gram	10-20			17.1
Mustard	8-12	2.56	0.175	0.73
Sorghum	8-12	1.69	0.124	0.85

Source: Engg. properties of Food materials (1980) CIAE Publication /80/15

4.6 WATER ACTIVITY

Water activity is an important characteristic of food grains. It influences odour, flavour, texture, colour, enzymatic activity and microbial load on the food product. Therefore, for safe keeping the food grains its knowledge and relationship with the atmosphere is must.

Water activity is a ratio of partial vapour pressure in a food product over the equilibrium vapour pressure of the product at the same temperature. In general for safe storage of food grains water activity should be below 0.6. However, to avoid lipid oxidation (which leads to rancidity in fats) water activity should be below 0.3. The most congenial atmosphere for growing the bacteria is when water activity is above 0.8 and for yeast and molds above 0.7.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why do we require to measure the size of the grains?

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2. Name two machines in whose designing terminal velocity is used?

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3. Define angle of repose of the grains.

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4. Name the instrument used for measurement of true density of the grains.

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5. List the characteristics of the grain influenced by the water activity of the storage.

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6. For safe storage of oil seeds, what is the water activity recommended.

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4.7 CLEANING AND GRADING

Cleaning is the first unit operations in any grain-processing unit. As the name explains, the purpose is to remove unwanted materials like chaff, stone, dust, and metallic pieces. In general, it is done with the set of sieves arranged one above other. The top sieve will have openings just equal to the size of the grains. The impurities bigger than the grain size are rolled above the screen and discarded. The grains and smaller impurities pass through the first sieve; fall on the second sieve, which have the openings smaller than the grain size. Here dust and smaller impurities pass through the sieve and collected separately. Clean grains roll over the screen and are collected. In general a fan is also attached with the cleaner. The fan blows/sucks the sufficient air to throw/carry away the finer impurities of the grains. Usually fan blows the air beneath the sieve. Thus, it helps in cleaning the screen to avoid choking of sieves. An oscillating screen cleaner with aspirator is shown in Figure 4.1.

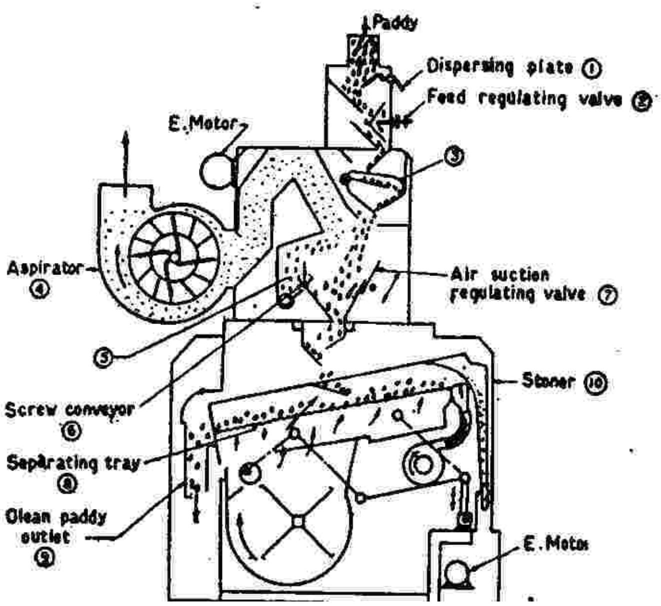

Figure 4.1: Oscillating screen cleaner with aspirator

In some cleaners, near the discharge end, a magnet is fitted. This magnet attracts the metallic impurities, which are removed manually at short intervals. Sieves may have round, oblong, rectangular or triangular openings depending on the requirement of the grains (Figure 4.2). In most of the cleaners, sieves are changeable to accommodate large variety of grains for cleaning. The oscillation speed of the sieve, feed rate and impurities composition decides the performance of the cleaner. In the modern cleaner, screen-cleaning brushes are fitted, which clean the screen to overcome problem of choking. Higher airflow of fan may carry away the grains and lower airflow may leave the impurities in the grain. So airflow based on terminal velocity of grains must be used.

Grading of grains is necessary as it aids to the value of the grains and helps in improving the performance and efficiency of processing machines. Grains, which are produced and harvested in the field, vary in their appearance, size, and location in the plant within the farm. If seeds sown are mixture of few varieties, the final produce may differ in the grain characteristics. The grading is defined as separation of the mixture in to separate sections based on their common quality characteristics. Grading is done based on size, wholesomeness of the grain, test weight, varietal purity, oil content, protein content, colour, hardness etc.

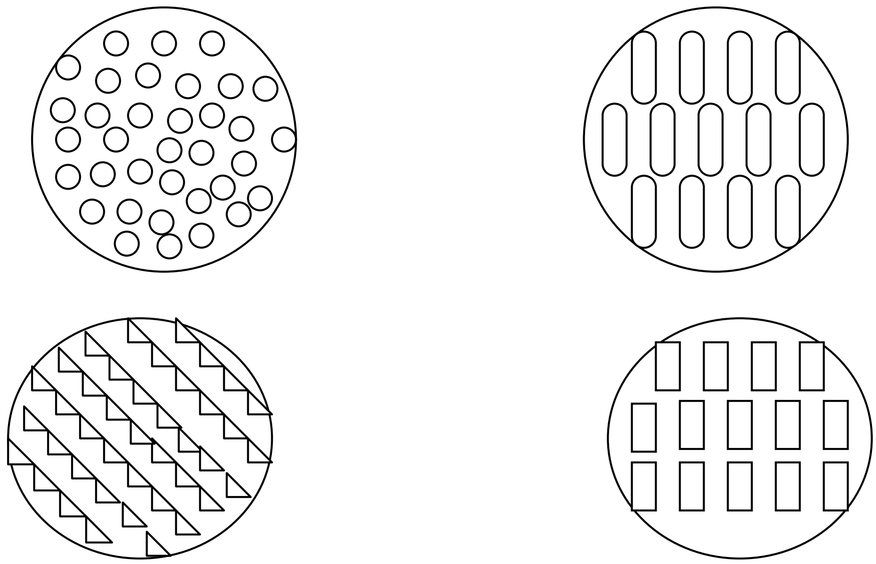

Figure 4.2: Different types of perforation on the sieve

4.8 PARBOILING CONDITIONING AND DRYING

Parboiling

Parboiling is a hydrothermal treatment given to grains specially paddy and wheat in order to make grain harder. In paddy, rice kernel become harder so that it could withstand the milling stresses and result in higher head yield. Parboiling is conducted in three steps namely soaking, steaming and drying. Soaking of paddy in the traditional method is done for 24 to 72 hours at the ambient temperature depending up on weather. In the modern method, soaking is done at 70^{o}C for 3½ hours. The void space between husk and kernel is filled with the water and moisture content of the grain is raised to 30% wet basis. After draining the excess water soaked paddy is steamed for 20-30 minutes. The moisture content of paddy is increased to 35% wet basis. Then paddy is dried to 14% moisture content. Traditional parboiling method has prolonged soaking, which imparts deep colour to the rice, off flavour, and some times in rainy season mold growth on the grains. In the modern parboiling method some of these defects are eliminated. In the process of soaking and steaming rice starch get gelatinized, protein get expanded and occupies the air space with in endosperm. It increases the cohesion and adhesion between starch granules and protein bodies. It also checks the cracks in rice kernel and it become stronger to withstand milling stresses.

During the process of parboiling vitamins of outer layer moves inside starchy endosperm and oil globules moves outside in the bran layer. Thus, after milling parboiled rice has more vitamins than raw rice and its bran has move oil content than raw rice bran. It is also found that due to heat treatment total water uptake, swelling index of parboiled rice is more than raw rice. Energy required in dehusking and loss of solids in the gruel is less in parboiled rice. The total rice turn out of parboiled rice is 70-73% which is 2-8% higher than raw rice and whole rice turn out is 60-65% which 20-30% more than raw rice.

Conditioning

Conditioning of grains specially pulses and oilseeds is done in order held or get better dal and oil recovery. Pulses are scratched, smeared with oil and water, dried in order to loosen the husk. Oilseeds are smeared with hot water prior to crushing to improve the oil recovery. Excess of wetting and drying of pulses affects their cooking quality as protein enclosed in the complex form, which changes its behaviour when hydrated and dehydrated.

Drying

Drying of grains is an important unit operation as it affects the ultimate quality of the grains. Grains {cereals 12-14%, pulses 10-12% and oil seeds 8-10%} moisture content is considered to be safe for storage.

Traditionally grains are dried in the drying yard with sun's energy. The grains are spread 5-10 cm thick layer and frequently turn to have uniform drying.

The limitations of the sun drying are:

- Weather dependent process
- Require more human energy for turning during drying
- Non-uniform drying
- Slow drying affects the quality of the product and increases the microbial load on the grains.

Thin layer drying through mechanical dryers with 10-15 cm thickness of the grain layer are the most common dryers used in the grain processing industry. Burning agricultural waste generates the heat, which is passed through heat exchanger. The hot air is blown and mixed with a falling bed of grains to get them dried. The main advantage of these dryers is the uniformity in drying and the drying time is reduced. These dryers are weather independent; require less space and energy.

In general drying air temperature depends on the type of grain, their moisture content and end use. For cereals, to be used for consumption, drying air temperature is to be limited to 70^{o}C, whereas for seed purpose it should be 45^{o}C. For oil seeds and pulses it should be 50-55^{o}C. Rapid drying develops fissures in the grain results in poor milling quality of paddy, affects, storability of wheat.

There are only few dal mills in the country where mechanical dryers are used. In general, sun drying is done for drying pulses in the process of dal milling (specially for pigeonpea the milling process takes 2-4 days longer depending on the weather.). Oil seeds are threshed/decorticated when fully dried. Conditioning is done to get maximum oil recovery. Generally dryers are not used in the oil industry.

4.9 GRAIN MILLING AND OIL SEED CRUSHING

Milling of cereals and pulses is a series of processing treatments prior to its conversion into edible form. These treatments vary from grain to grains. Flow chart for milling of paddy, pulses and oil seed given in Figures 4.3, 4.6 and 4.7.

4.9.1 Rice (Paddy) Milling

Paddy raw or parboiled is cleaned to remove all the impurities. Cleaned paddy fed in a sheller / dehusker. Traditional dehusker is an Engleberg rice huller. A huller is small mill operated by motor with a capacity 500-750 kg/h. The mill consists a cast iron roller, where shelling and polishing is done simultaneously. Therefore, bran, brokens are mixed with the husk, which is difficult to separate. As the moving part is cast iron roller, it results higher broken pieces during milling. Though, the machine is simple in operation, low in cost but results poor milling yield (total yield 62-64%, Head rice 40-50%).

The other low capacity paddy milling machines are centrifugal sheller and under runner disc sheller. A mini modern rice mill (Fig. 4.4) consists of feed hopper, rubber roll sheller, husk aspirator and a polisher in a single composit unit. The modern paddy sheller is rubber roll sheller. In it two rubber rolls are rotating in opposite directions at different speeds. Difference in surface speeds of rollers develops shearing action and results in removal of husk. Using rubber rollers only husking is done, in the machine. A blower sucks the husk and paddy-rice mixture is fed on a separator. In general, there are two types of paddy separator namely compartment type or deck type separators are used in the rice mills. Both the separators work on the principle of gravity separation. The heavier material rice remains in touch with the surface and moves along with the separator surface and carried against the gravity to upper side and discharged. Paddy being lighter moves with the gravity down and recycle to the sheller for shelling. Paddy rice mixture is recycled back to the separator. Only rice is fed in the polisher, where due to abrasion rice are polished and upper aleurone layers are removed. These layers are rich in oil content (14-26%). Rice bran is collected through cyclone separator and rice is fed in the grader. Whole rice are separated from the brokens parts through a grader. A typical flow diagram of modern rice mill is shown in Figure 4.5.

4.9.2 Wheat Milling

Traditionally wheat is milled in an attrition mill, where or (Break rolls) grains are fed in the center, moves radially out, between two emery/stone discs. Grains are compressed and sheared. The clearance between stones/is gradually reduced and whole grain flour is obtained. As the size from whole grains is reduced to fine in one go, there is significant rise in the temperature. It affects the quality of flour.

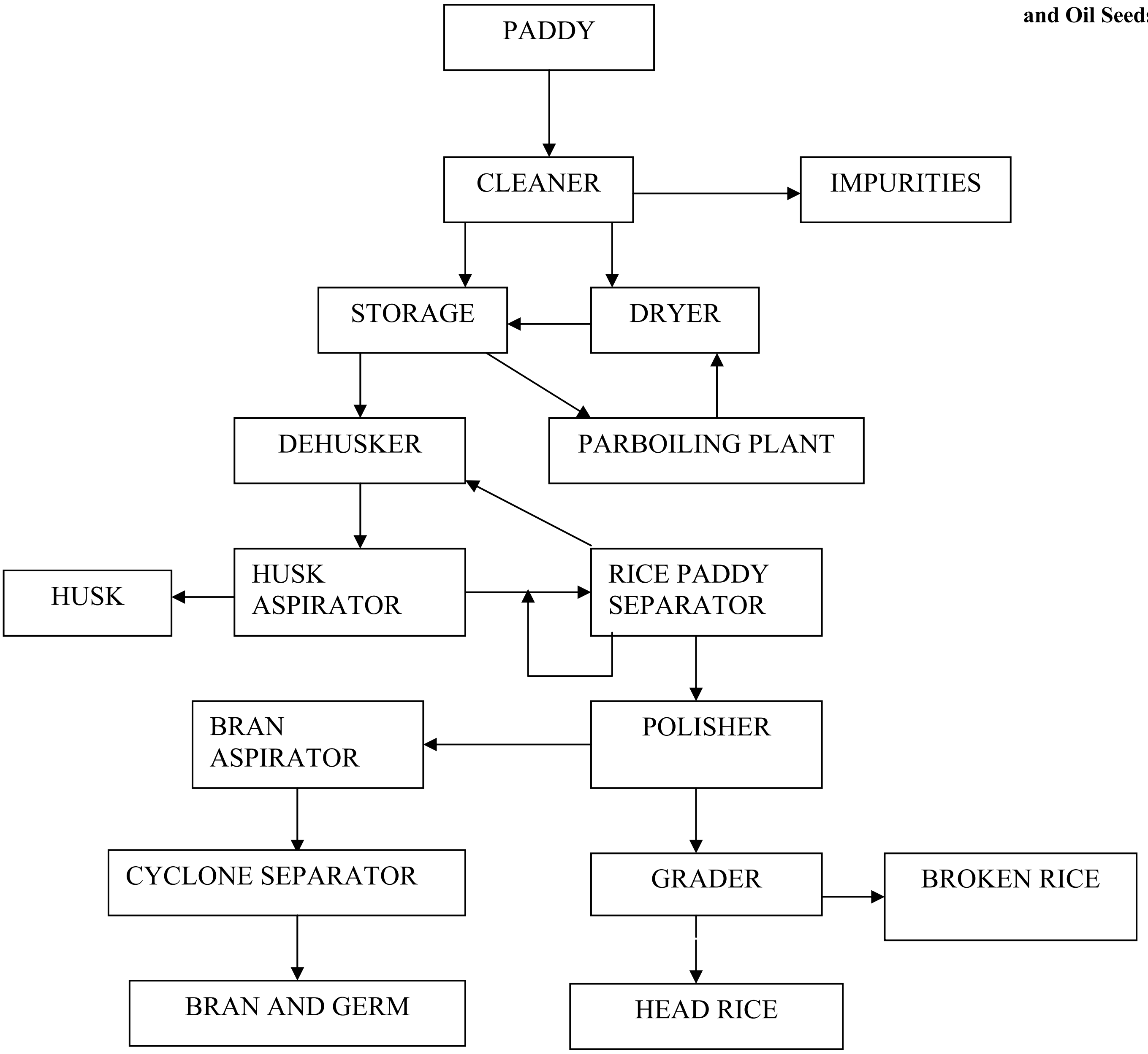

Figure 4.3: Process Flow Chart of Modern Rice Milling

Modern wheat mill consists of series of reduction rollers (about 15 to 18) where different fractions, Suji, maida etc are separated. Since size is reduced gradually, rise in temperature doesn't take place and quality of the constitutes is better.

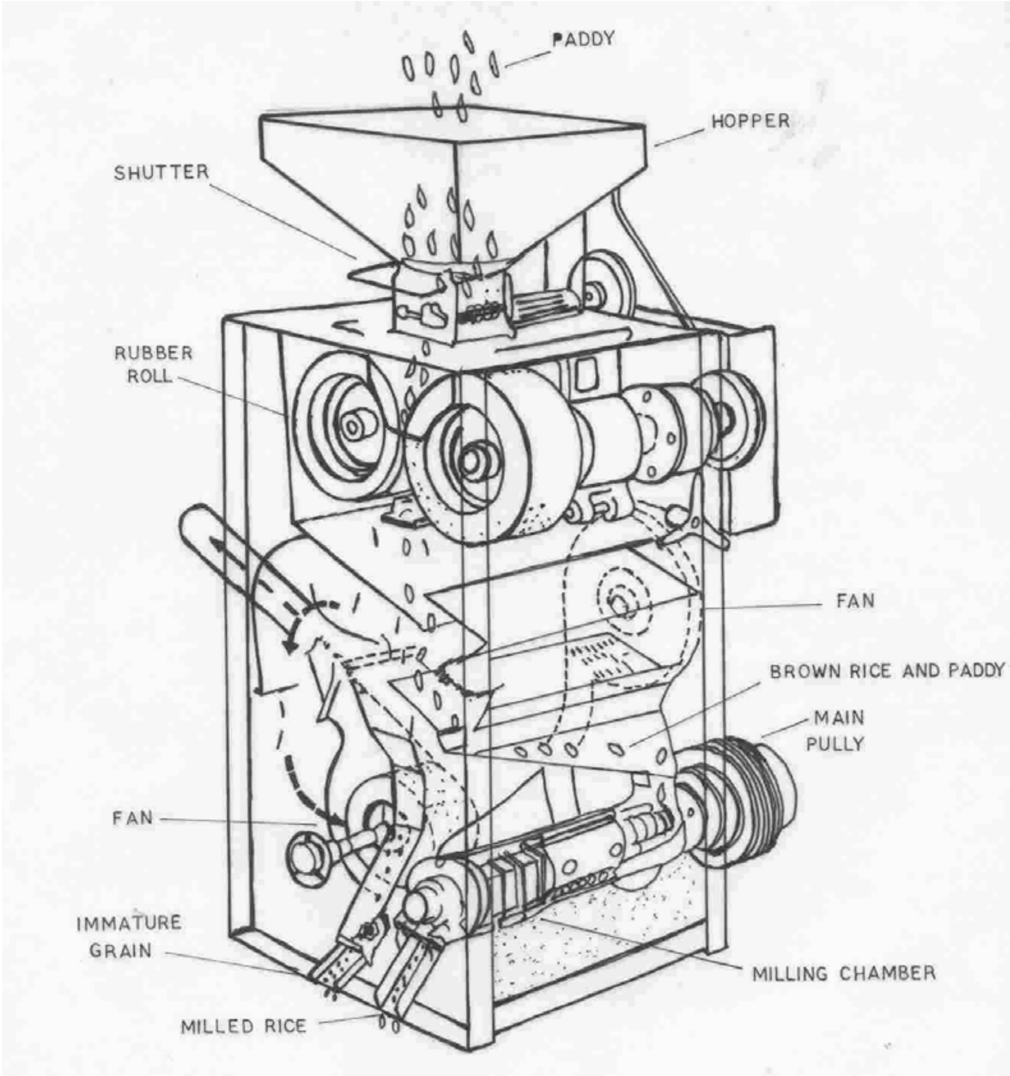

Figure 4.4: Mini modern rice (paddy) mill

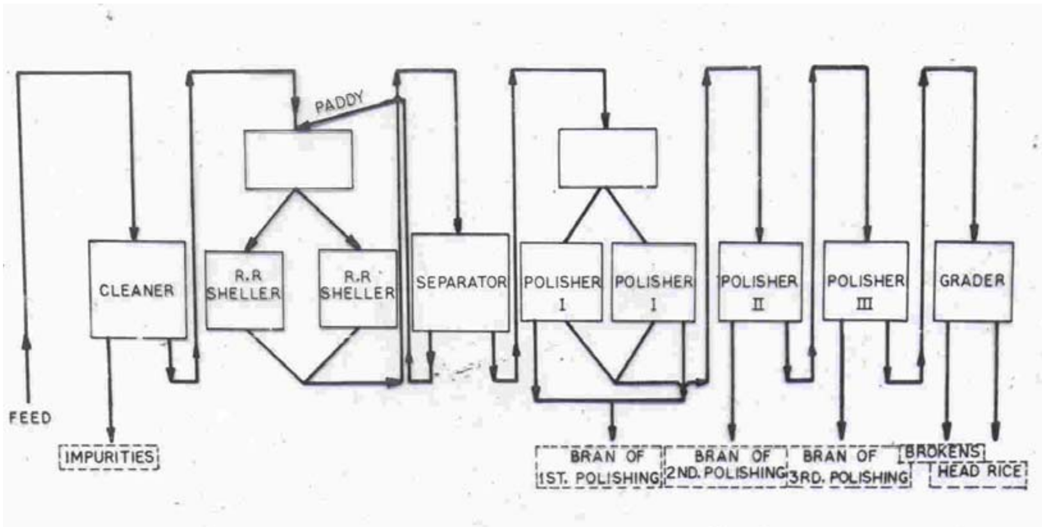

Figure 4.5: Typical Flow Diagram of Modern Rice (Paddy) Mill

4.9.3 Corn Milling

Corn can be milled by dry milling or wet milling. In dry milling moisture is raised to 24-25% and germ is separated by Beall degermer. Rest grain is dried and milled. In wet milling, corn is soaked in water (50°C) for 1-2 days. Germ is separated for oil extraction and rest is centrifuge to make starch, dextrin, sugar syrup etc. The water used for soaking is also drained and concentrated to 35-55% solids to be used for pharmaceuticals.

4.9.4 Pulse Milling

Pulses are rich source of protein. They are traditionally milled dry. Except pigeon pea, milling of pulses is easy as binding between husk and cotyledon is poor. For pigeon pea it is most difficult.

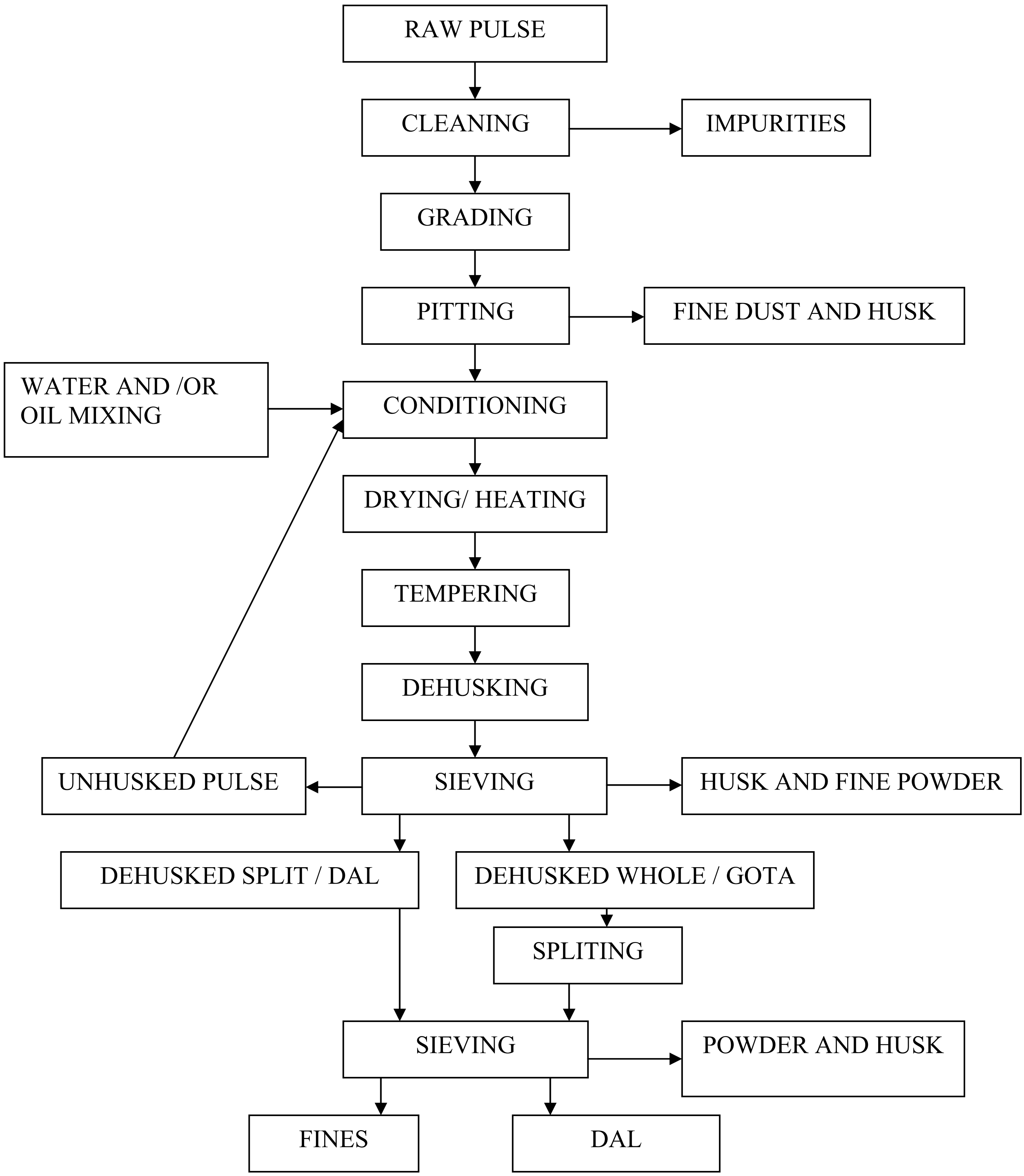

Figure 4.6: Process flow chart of improved pulse milling

Traditional milling of pigeon pea includes cleaning, scratching, treating with oil, and wetting, mixing with red earth, conditioning, scratching and splitting. In general, it yields 65-70% of dal recovery against potential of 81-84%. In modern pigeon pea milling, which includes cleaning, preconditioning, dehusking separating and splitting. It provides 72-78% dal recovery. The preconditioning includes addition of moisture, oil and drying in LSU dryer. In the modern method dal can be prepared in 1-2 days from pulses whereas in the traditional process it takes 5-10 days. A process flow chart of improved pulse milling as shown in Figure 4.6.

4.9.5 Oil Seed Crushing

Oil seeds like groundnut, castor etc are decorticated in manual or motorized decorticator. Clean seeds are crushed either in ghani operated by bullocks or mechanical power or in screw press oil expeller.

Ghanis are made of wooden taper barrel, where pestle is rotated in it. In general, 6-12 kg oil seeds are fed and hot water 1-5% is added in a batch, which takes 45 minutes to crush. A ghani recovers 60-75% of the total available oil in the oil seeds.

A screw press oil expeller is 6 to 12 bolt expeller having series of worms of different pitches. Due to pressure built up inside the horizontal casing, oil oozes out. The capacity of the expellers are to crush 60 to 120 kg oil seeds/ batch and recovers 80-85% of total available oil in two to three passes. Commercially 8 power ghanis with one mechanical oil expeller are in practice. Firstly, oil seed is crushed in ghanis and residual oil cake is passed through expeller. However, even after that 6-7% oil remains in the residual cake, which is extracted through solvent extraction process. Process flow chart of oil seed processing is given in Figure 4.7.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Differentiate cleaning and grading.

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2. State merits and demerits of parboiling of paddy.

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3. Why conditioning of pulses and oilseeds is done during processing?

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4. “Rapid drying of grains is not recommended”. Why?

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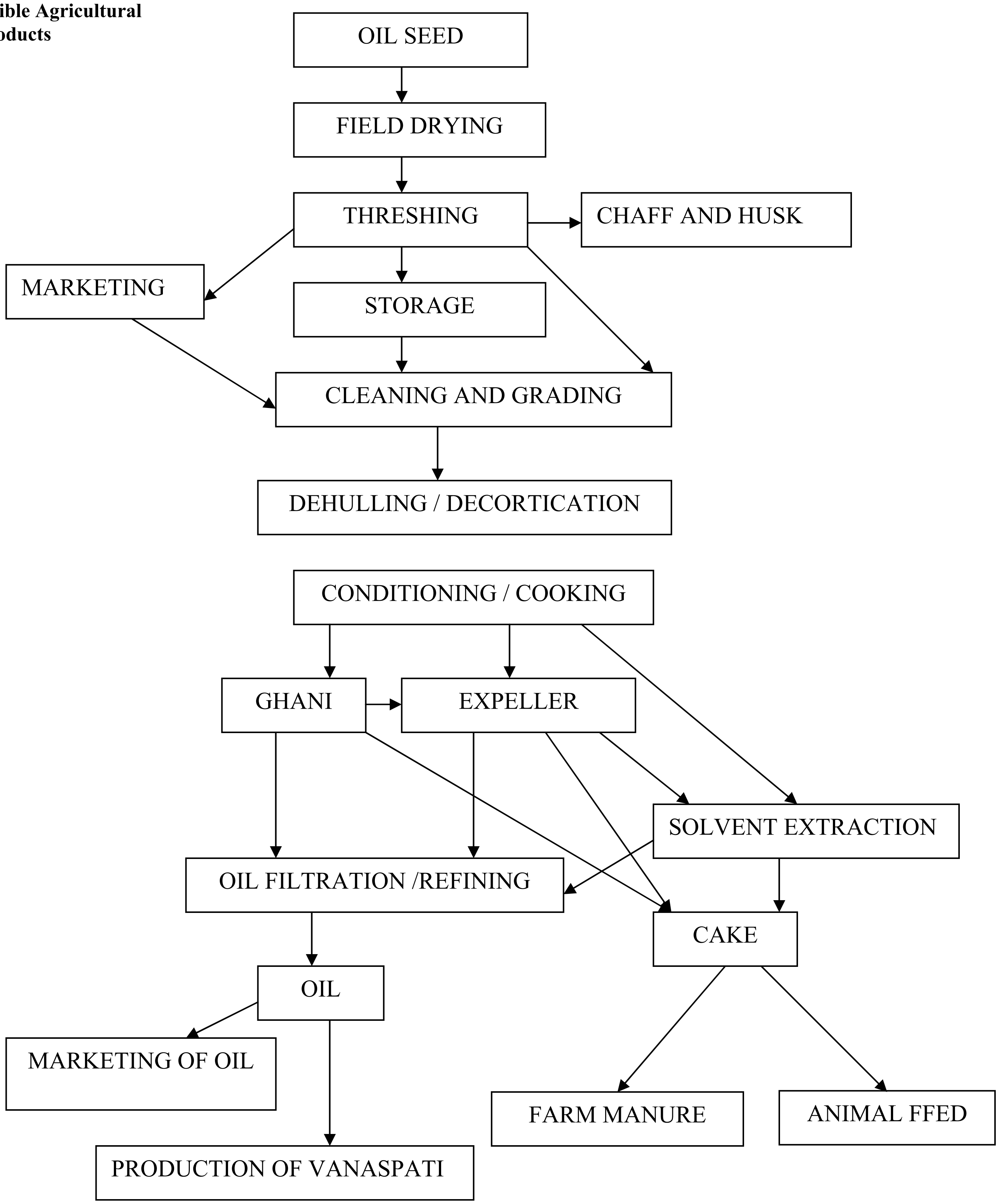

Figure 4.7: Process flow chart for oil seed processing

4.10 STORAGE OF GRAINS

Primary function of storage is to prevent food loss during the storage. The loss means any change in the availability, edibility, wholesomeness or quality of the food that prevents it from being consumed by people. Losses may be direct or indirect. A direct loss is disappearance of food by spillage, or consumption by insects, rodents, birds etc. An indirect loss is lowering of quality to the point where people refuse to eat it. All the types of losses could be conveniently categorized into two categories i.e. quantitative and qualitative.

Causes of deterioration of food grains are:

A) Environment
   i) Temperature
   ii) Ambient RH
   iii) Gaseous composition $\{O_2:CO_2:N_2\}$

B) External Micro-organisms
   iv) Insect
   v) Pest (birds, rodents)
   vi) Mites, fungi, bacteria, yeasts

C) Biochemical composition of the grain
   vii) Moisture content
   viii) Fat content

Changes occurring during storage on the grains are:

A) Wholesomeness/purity
   i) Excreta
   ii) Dockage-impurities
   iii) Damage grains

B) Quality of the grains
   iv) Weight loss
   v) Taste
   vi) Colour
   vii) Odour
   viii) Nutrition
   ix) Fat acidity
   x) Toxicity
   xi) Germination
   xii) Moisture content
   xiii) Post harvest quality: Milling and baking quality

Moisture is the most important factor, if taken care can limit development of bacteria, fungi, mites and insect attack which cause the spoilage of the grain during storage.

Some tips are:

1. Uniformly dried grains below 13% moisture content usually do not have growth of most of the microorganisms and mites.

2. Insect cannot attack the grains having moisture content below 10%.

3. In bulk storage, moisture content of the grain seldom remains uniform. Relative humidity of store, outside environment condition develops air currents. Thus within the bulk storage high and low moisture pockets develop. To check them, periodic inspection at these points is a must.

4. It is desired that relative humidity of the store should be 50-60%. Lower humidity results in over drying of the grains and develop fissures which affects milling, baking, cooking quality of the grains.

5. Higher humidity will increase the moisture content and grains are likely to be attacked by insects-pests and microorganisms.

6. Grains should be stored in dry and cool place. As the moisture content of the grains is directly proportional to the respiration of the grains.

7. The increase in respiration increases the temperature, growth of microorganisms and enzymatic activity of the bulk grain up to certain temperature.

8. Mites do not develop if the storage temperature is below 5°C, insects do not grow if the storage temperature is below 15°C and fungi do not develop if the storage temperature is below 0°C.

9. Most favourable temperature for insect growth is 25-30°C.

An ideal storage structure should:

- have adequate protection against insect-pest.
- maintain wholesomeness and purity
- be air tight during fumigation and allow air movement during ventilation
- be easy to inspect and clean.

In India, major portion of produce is stored in a large number of small capacity rural godowns. These godowns are neither air tight nor safe from insect-pest and rodent. It is estimated that the losses in such rural godowns is as high as 30 % in humid conditions if stored for 8-10 months. The grains with scientific storage are stored in the bulk either in bag storage or in silos. The bag storage has following advantages:

✓ Small lots of a number of crops or varieties can be stored in the same space

✓ Infested bags can be easily segregated and fumigated.

✓ Each bag can be handled independently

After the green revolution our food grain production has increased many fold. However, the warehouse capacity is limited. Therefore, for short period food grains are stored in CAPS (cover and plinth storage). The maximum safe storage period for CAPS is only 6 months under ideal conditions, but in practice grain is stored in CAPS even up to 2 to 3 years. It is mainly due to poor infrastructure facility for storing food grains in bulk or godowns.

The most modern and safe method of storage of single type food grains is silo. The advantages of storing in silos are:

❖ Greater storage capacity per unit volume of space,

❖ Loading and unloading is easier and cheaper as mechanical handling devices do it.

❖ No cost of purchasing gunny bags and dunnage

❖ No danger of rodents as they are metal or RCC bins/silo

❖ Insect infestation is considerably less and if required easy to fumigate.

- ❖ Minimal effect of outside environment on food grains and if required easy to turn with the help of mechanical handling devices.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the causes of food grain deteriorations?

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2. List the characteristics of ideal storage structure for food grains.

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3. Compare the bag storage and silo storage methods.

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4. What is the temperature, relative humidity of the environment and moisture content requirement of the grain for safe storage.

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4.11 VALUE ADDED PRODUCTS

There is a great scope for diversification and value addition to cereals, pulses and oil seeds. Consumer preferences especially in urban areas for processed, fast foods have gained significantly. Media and television have played a significant role for domestic market. Even developed and other countries are looking towards India as a big market for processed foods. Now–a-days time is the biggest constraint with the urban people. So ready to eat, fast to cook, extruded, puffed, baked snacks are convenient have great potential in the market. Some of the possible products are listed in Table 4.5.

Besides these blended products as functional foods have domestic and export market. Functional foods are modified foods that help to improve health (provide specific health benefit) and prevent diseases when ingested. Some examples are:

- **Energy bars:** Constitute simple sugar to complex, contain about 12 % fat; 8-20 % protein and can be fortified with vitamins and minerals. It is specially made for athletic group.
- **Weight loss bars:** Balance nutrition with control calories intake and fortified with vitamins and minerals.
- **Breakfast bars:** High carbohydrate, low protein and fortified with vitamins and minerals.
- **Nutrition bars:** High protein content (15-27 g per serving) for body builders and fortified with vitamins and minerals.

Containing essential vitamins and amino acids for heart patient, diabetic patient, obey people etc.

Table 4.5: Value added products from cereals, pulses and oilseeds

Grains	Existing products	Newer products
Paddy	Raw and parboiled rice; puffed and flaked rice and rice flour	Quick cooking rice; pasta products; rice based snacks and rice bran oil
Wheat	Flour; maida; suji; dalia; and noodles	Durum wheat; puffed product and extruded products
Corn	Flour; flakes; popcorn; starch; dextrose and dextrin	Corn oil and degermed corn flour corn chips
Pulses	Dal; Powder; roasted grains; animal feed (husk)	Mixed flour; blended products; fortified products; instant dal and dal analog
Millets	Flour and puffed	Blended products and baked products
Oil seeds	Oil and cake for feed and fertilizer	Edible deoiled cake as flour; protein isolate from soy flour and blended flour

4.12 BY-PRODUCT UTILIZATION

In the present day competition an industry has to use every source of earning from the product and by-products. Moreover, unutilized by-products are an effluent to the industry. As per the environmental regulation these effluents had to be safely disposed off so that they do not pollute the environment or surroundings.

In general grains, pulses and oil seed milling units have solid by products. Some of these by-products if properly processed and used can become more profitable than the main product. A list of some by-products of cereals, pulses and oil seed milling and their possible value added products or utilization is given in Table 4.6.

Table 4.6: By-products and their utilization in the vale added products

Grain	By-product	Utilization
Paddy	Husk	Fuel: Heating value 3000-3500kcal/kg. Insulating, packaging and building material. Husk ash mixed with hydrated lime produces cement like material. Husk as an abrasive. Producing activated carbon, sodium silicate for soap industry. Pure silicon can be produced from rice husk. Silicon carbide and silicon nitride can also be produced.
Rice	Rice bran	Rice bran oil as edible oil. Defatted bran as cattle feed. Defatted bran as fertilizer. Defatted bran contains vitamins like B complex, B_1, B_6, amino acids, phosphoric acid compounds etc. for medicinal and dietetics use. Defatted bran for bakery purposes. Crude rice bran oil is used in industries, for soap, cosmetics, plasticisers, emulsifiers, protective coating, synthetic fibre etc.
Rice	Broken rice	Pasta products, rice flour, production of starch, and alcohol.
Soya bean	Defatted soya cake	Defatted soya flour for soya nuggets, soya laddu, soya granules and blended flour, soy isolates & concentrates.

4.13 LET US SUM UP

Food grains play an important role in the national economy and a day-to-day requirement of human being. Post harvest handling, storage and processing of food grains is an important operation, which can create large amount of employment at all the sectors. Moreover, it has scope to reduce the post harvest losses, which amounts to be Rs. 20,000/- crore annually. Indigenously designed food processing machines based on the properties of the grains has another employment avenue. Traditional processing technologies and machines are consuming more energy, producing poor quality turnout and results in high losses. Therefore, improved machines and technologies can solve some of these problems. However, their capacity of processing is high. There is a need to develop proper storage techniques to reduce the loss of quality and quantity of the grains during storage. Food grains can be used to produce many value added convenience products to meet special requirements. Utilization of the by-products can make food-processing industry more viable.

4.14 KEY WORDS

Sphericity : It is the ratio of the geometric mean of 3-major axis with the largest axis dimension of the grain.

Angle of repose : It is the angle between the base and slope of the cone formed, when grains are freely dropped on the horizontal plane.

Cleaning : Removal of impurities from the grains.

Grading : Separation of the grains based on their value.

Parboiling : It is hydrothermal treatment given to cereals in order to improve their milling quality.

Silo : Modern bulk storage structure where single type of grains can be stored for longer duration.

Functional foods : Modified food that help to improve health and prevent diseases when ingested.

4.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Industry and agriculture are two pillars of Indian economy.

2. “Whole world is looking towards India as a big market” because of large population (more than 1 billion) and unorganized food processing sector.

3. The chemical composition of the grains depend upon the crop, variety, environment in which crop is grown, type of soil, water and fertilizer applications while raising the crop.

4. The solubility of starch increases with the increase in the temperature.

5. Post harvest losses in the pulses are mainly during milling. Theoretical expected dal yield is 81-84% but actual recovery is 68-72%.

Check Your Progress Exercise 2

1. The size of the grains helps in designing the cleaner, grader and some other processing machines.

2. Winnowing and pneumatic conveying are two machines, in which terminal velocity is used for designing.

3. **The angle of repose** of the grains is the angle between the base and the slope of the cone formed, when grains are freely dropped on the horizontal plane.

4. Pycnometer is used for measuring the true density.

5. Water activity influences odour, flavour, texture, colour, enzymatic activity and microbial load of the grain.

6. For safe storage of oil seed the water activity of the store should be below 0.3.

Check Your Progress Exercise 3

1. Cleaning is to be done in the beginning of the processing, where grading is done either in between or at the end to improve the economic value, performance of processing, or storage as the case may be.

2. In parboiling the grain become harder and can withstand the milling stress. Therefore, milling improves the yield. The process of parboiling involves partly fermentation so that the parboiled rice develops off flavour and dark colour.

3. Conditioning of pulses help in loosening the husk. So milling becomes easier. Conditioning of oil seed improves oil recovery.

4. Rapid drying develops fissures on the grain. Thus during milling it breaks and its storability is poor.

Check Your Progress Exercise 4

1. The causes of food grain deteriorations are:

   (A) Environment: Temperature, Ambient RH, Gaseous composition $\{O_2:CO_2:N_2\}$

   (B) External Micro-organisms: Insect, Pest (birds, rodents), Mites, fungi, bacteria, yeasts

   (C) Biochemical composition of the grain: Moisture content, Fat content

2. Characteristics of ideal storage structures are:

   - Adequate protection against insect-pest.
   - Maintain wholesomeness and purity.
   - Sufficient air tight during fumigation and air tight during ventilation.
   - Ease in inspection and cleaning.

3. The comparison of bag storage and silo storage system:

Bag storage	Silo storage
Small lots of a number of crops or varieties can be stored in the same space	Only one commodity can be stored. However, Greater storage capacity per unit volume of space is available
Infested bags can be easily segregated and fumigated	Insect infestation is considerably less and if required easy to fumigate. No danger of rodents as they are metal or RCC bins/silo
Each bag can be handled independently	Loading and unloading is easier and cheaper as mechanical handling devices do it.

4. Ideal storage temperature below is 15° C, Relative humidity 50-60% and moisture content of the grain between 10-13% for safe keeping of the grains.

4.16 SOME USEFUL BOOKS

1. Chakraverty, A. (2000) Post Harvest Technology of Cereals Pulses and Oilseeds (3rd Edition) Oxford and IBH Publication Co. Pvt. Ltd. New Delhi.

2. Chakraverty, A.S. Mujumdar, G.S., Raghavan, V. and Ramaswamy, H.S. (2003) Hand Book of Postharvest Technology of Cereals, Fruits, Vwegeatbles, Tea and Spices. Marce; Dekker Inc., New York.

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4. Hall, D.W. (1980) Handling and Storage of Food Grains in Tropical and Sub-tropical Areas. FAO, Rome.

5. Sahay, J. (1977) Elements of Agricultural engineering (Vol. I). Agro Book Agency Patana.

6. Kuprits, Y.N. (1967) Technology of Grain Processing and Provender Milling. Israel Programme for Scientific translation, Jerusalem.

UNIT 5 FRUITS AND VEGETABLES

Structure

5.0 OBJECTIVES

After reading this unit, you should be able to:

- know production, composition, properties and factors responsible for determination of quality of fruits and vegetables and their control;
- describe post harvest handling, processing and storage of fruits and vegetables and by-product utilization of fruits and vegetables; and

- explain techno-economic feasibility of some small-scale fruits and vegetable base processing industry.

5.1 INTRODUCTION

Fruits and vegetables have an important place in our day-to-day life. Being rich in minerals and vitamins they are called protective foods. India's economy is based on the agriculture. India is one of the largest producers of fruits and vegetables in the World play a very significant role in the national economy.

India's geographical location and topography provides an excellent opportunity to produce every thing in our country. However, round the year availability of fruits and vegetables provides passive response towards commercial processing of fruits and vegetables. The people also have poor acceptability of processed foods. This often led to glut, more post harvest losses besides less contribution of processed foods in the national economy.

5.2 PRODUCTION AND IMPORTANCE

Fruits and Vegetables play an important role in agriculture, human health and national economy. In India, a decade back production of fruits and vegetables was just 50% of food grains production but it has been raised to 66% and anticipated that by 2010 it will be 80%. India is the second largest producer of fruits and vegetables in the world. India produces about 100,000 corers of rupees worth fruits and vegetables every year. However, a considerable amount of this produce in lost due to negligence and improper post harvest handling, which amounts to be 25 to 30%. Besides, this huge financial loss the wastage also affect the per capita availability of fruits and vegetables. It results in quality of health and life of majority of the people of the country.

You know, India with round the year sunshine, variate soil type, climate and topography produces variety of fruits and vegetable. Our nation is the largest producer (Table 5.1) of mango, banana, papaya, sapota, cashewnut, coconut, cauliflower, okra, capsicum, pea etc.

Though, our country is one of the highest producer of the fruits and vegetables but productivity is significantly lower in most of the fruits and vegetables as per the international bench mark (Table 1). The lower yields are mainly due to poor quality of planting material including varieties, unplanned farm management practices like fertilizer, water management and small from holding. However, some farmer have obtained better yield with competitive quality of international standard.

Table 5.1: Area, production, productivity of some fruits and vegetables

Fruits or vegetables	International benchmark (t / ha)	Area ('000 ha)	Production ('000 t)	Productivity (t / ha)	Percent world contribution (%)
Banana	35.5	491	16813	34.3	29 (I)
Mango	30.0	1487	10504	7.1	44 (I)
Papaya	-	60.5	1666.2	27.5	30 (I)
Citrus	24.5	527	4651	8.8	3
Guava	-	151	1711	11.3	- (IV)
Pineapple	60.0	76	1025	13.6	8 (III)
Sapota	-	64	800	12.4	- (I)
Coconut	-	1778	8429	4.7	18 (I)
Cashewnut	-	686	520	0.76	44 (I)
Cauliflower	-	248	4718	19.0	34 (I)
Pea	-	273	2712	9.9	38 (I)
Okra	-	349	3419	9.8	- (I)
Tomato	25.9	457	7427	16.3	9 (III)
Potato	-	1341	25000	18.6	8 (III)
Cabbage	-	258	5909	22.9	12 (II)
Brinjal	-	500	8117	16.2	38 (II)
Onion	-	493	4899	9.9	11 (II)

Source: NHB Data Book 2002

In spite of huge production, India shares only 2.3% of the world trade of fruits and vegetables. It also process only 2.5% of the total produce in a organized sector whereas Thailand 30%, Brazil 70%, Philippines 78% and Malaysia 80%. One of the reason is the varieties have poor recovery of process product for i.e. Indian tomatoes have 4 ^{o}b of total solids whereas varieties in European countries have 6 ^{o}b. Thus, to produce same quantity of tomato end product 50% more tomatoes are required in our country.

Fruits and vegetables processing industry ranks 5th in its size and employees 19% of work force which is about 1.6 million people. It accounts for 14% total industrial output against 5.5% industrial investment and contribute 18% to the GDP. Annual turnover of fruit and vegetable industry is Rs. 1800 billion and out of which Rs. 1400 billion are from unorganized sector.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name three fruits and three vegetables in whose production our nation ranks first in the world.

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2. Give two reasons for huge post-harvest losses of perishables.

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3. List the reasons for low farm yield as compared to the international benchmark.

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5.3 TYPE OF FRUITS AND VEGETABLES

The fruit is derived from the Latin word "fructose" which means to enjoy, produce. The fruit is a product of fertilization and is a ripened ovary. Fruits are classified into pome (apple and pear); stone (mango, peach, plum, cherry), berry (strawberry, tomato); nut (walnut, cashewnut); hesperidium (citrus); synconium (fig), sorosis (mulberry); coenocarp (jack fruit) and syncarp (custard apple).

The vegetables develop from variety of plant parts (cabbage pea, potato). On the basis of plant parts used as vegetables they are grouped as fruits (gourds, brinjal, capsicum); stem (asparagus, amaranths), leaves (cabbage, lettuce, spinach) flowers (broccoli, cauliflower) and underground portion (radish, carrot, potato, onion, garlic).

For processing or storage purpose fruits are also classified as climacteric and non-climacteric fruits. The climacteric fruits are those, which develop total senescence sometime after the harvest during storage. For e.g. apple, banana, ber, fig, guava, mango, pear, peach, papaya, sapota, tomato. Whereas non-climacteric fruits ripen on the plants. for i.e. citrus, grape, litchi, pineapple, pomegranate, strawberry etc. The climacteric fruits have high rate of respiration and production of carbon dioxide and ethylene than the non-climacteric fruits during the process of ripening. It leads to change in colour, flvaour, texture and some chemical changes.

5.4 COMPOSITION AND FOOD VALUE

You know that fruits and vegetables are considered as protective foods as they are major source of nutritients such as vitamins and minerals. The quantity and quality of these nutrients vary with the variety, pre-harvest practices and maturity. These nutrients imparts their colour, flavour, and texture. Colour of the fruits is basically due to sugar derivatives of anthocynidins. Flavour in the fruits depends on the proportion of sugars and acids. Besides that there are some volatiles flavouring compounds. The texture of the fruits is governed by polysaccharides. Fruits are also containing phenolics compounds. They impart astringency, bitterness and aroma, which provide resistance to pathogens and stress.

Food value namely major constituent, vitamins and minerals of some important fruits and vegetables have been given in Table 5.2 A, B and C at their maturity stage.

5.5 PHYSIOLOGY OF FRUITS AND VEGETABLES

Physiological maturity is the state of harvest of fruits and vegetables, which provides some flexibility of time for marketing the produce, so that produce attain desirable eating quality when it reaches the consumer. The produce harvested prior to attainment of physiological maturity exhibit lack of flavour and loose moisture rapidly. If harvested late may be overripe and have very short post harvest life.

Objective and subjective methods for assessing the maturity of fruits and vegetables have been standardized. They are classified as :

- Physical methods
- Chemical methods
- Biochemical methods

Table 5.2a: Food values of fruits and vegetables

Name of produce	Major constituents (percent)					
	Moisture	Protein	Fat	Mineral matter	Fiber	Carbohydrate
Fruits						
Apple	85.9	0.9	0.1	0.3	-	13.4
Aonla	81.2	0.5	0.1	0.7	3.4	14.1
Banana	61.4	1.3	0.2	0.7	-	36.4
Guava	76.1	1.5	0.2	0.8	6.9	14.5
Lime	84.6	1.5	1.0	0.7	1.3	10.9
Mango	86.1	0.6	0.1	0.3	1.1	11.8
Orange	87.6	0.9	0.3	0.4	-	10.6

Papaya	89.6	0.5	0.1	0.4	-	9.5
Pear	86.9	0.2	0.1	0.3	1.0	11.5
Pineapple	86.5	0.6	0.1	0.5	0.3	12.0
Tomato	94.5	1.0	0.1	0.5	-	3.9
Leafy vegetables						
Cabbage	90.2	1.8	0.1	0.6	1.0	6.3
Drum stick	75.0	6.7	1.7	2.3	0.9	13.4
Radish leaf	87.4	2.2	0.5	2.6	2.2	5.1
Spinach	91.7	1.9	0.9	1.5	-	4.0
Roots and Tubers						
Carrot	86.0	0.9	0.2	1.1	1.2	10.7
Onion	86.8	1.2	0.1	0.4	-	11.6
Potato	74.7	1.6	0.1	0.6	-	22.9
Radish	94.4	0.7	0.1	0.6	-	4.2
Sweet Potato	68.5	0.7	0.2	1.0	-	38.7
Yam	78.7	1.2	0.1	0.8	0.8	18.4
Other Vegetable						
Brinjal	91.5	1.3	0.3	0.5	-	6.4
Ash gourd	96.0	0.4	0.1	0.3	-	3.2
Cauliflower	89.4	3.5	0.4	1.4	-	5.3
French been	91.4	1.7	0.1	0.5	1.8	4.5
Cucumber	96.4	0.4	0.1	0.3	-	2.8
Lady Finger	88.0	2.2	0.2	0.7	1.2	7.7
Pea	72.1	7.2	0.1	0.8	-	19.8
Pumpkin	92.6	1.4	0.1	0.6	-	5.3
Snake gourd	94.1	0.5	0.3	0.7	-	4.4

Source: NIN, ICMR, Hyderabad, 1999

Table 5.2b: Food values of fruits and vegetables

Name of Produce	Minerals, (mg /100 g)								
	Cal-cium	Phos-phorus	Iron	Magne-sium	Sod-ium	Pota-ssium	Copper	Sul-phur	Chlo-rine
Fruits									
Apple	10	20	1700	7	28	75	0.13	7	1
Aonla	50	20	1200	-	5	225	0.18	-	-
Banana	10	50	400	34	36.6	88	0.40	7	8
Guava	10	40	1000	8	5.5	91	0.34	14	4

Lime	90	20	300	-	-	270	0.16	-	-
Mango	10	20	300	27	26	205	0.20	17	3
Orange	50	20	100	9	4.5	93	0.58	7	5
Papaya	10	10	400	11	6	69	0.20	13	11
Pear	10	10	700	-	-	-	-	-	-
Pine-apple	20	10	900	20	34.7	37	0.36	20	13
Tomato	10	20	100	12	12.9	146	0.14	11	6
Leafy Vegetables									
Cabbage	30	50	800						
Drum stick	44	70	7000						
Radish leaf	12	90	4800						
Spinach	60	90	5000						
Roots and Tuber									
Carrot	80	40	1500						
Onion	180	30	700						
Potato	10	50	700						
Radish	50	30	400						
Sweet Potato	30	40	900						
Yam	50	20	600						
Other Vegetable									
Brinjal	20	60	1300						
Ash gourd	30	20	500						
Cauli-flower	30	60	1300						
French been	50	30	1700						
Cucu-mber	10	30	1500						
Lady Finger	90	80	1500						
Pea	20	80	1500						
Pumpkin	10	30	700						
Snake gourd	50	20	1300						

Source: NIN, ICMR, Hyderabad, 1999

Table 5.2c: Food values of fruits and vegetables

		Vitamin				
Name of Fruit/ Vegetable	**Calorific value (cal/100g)**	**Vitamin A (IU/100g)**	**Vitamin B (mg/100g)**	**Vitamin C (mg/100g)**	**Nicotinic acid (mg/100g)**	**Riboflavin (mg/100g)**
Fruits						
Apple	56	-	0.03	2	0.2	0.03
Aonla	59	-	0.03	700	0.2	0.03
Banana	153	-	0.04	19	0.3	0.03
Guava	66	-	0.03	300	0.2	0.03
Lime	59	26	0.02	63	0.1	0.02
Mango	50	4800	0.04	24	0.3	0.05
Orange	49	350	0.05	68	0.3	0.06
Papaya	40	2020	0.04	46	0.2	0.05
Pear	47	14	0.02	-	0.2	0.03
Pineapple	50	60	0.03	63	0.2	0.04
Tomato	21	320	0.04	32	0.4	0.05
Leafy Vegetables						
Cabbage	33	2000	0.06	124	0.4	0.12
Drum stick	96	11300	0.06	220	0.8	0.12
Radish leaf	33	6700	0.05	65	0.5	0.12
Spinach	32	5500	0.05	48	0.5	0.11
Roots and Tubers						
Carrot	47	2000-4300	0.04	3	0.4	0.02
Onion	51	-	0.08	11	0.4	0.01
Potato	99	40	0.10	17	1.2	0.01
Radish	21	-	0.06	15	0.4	0.02
Sweet Potato	159	-	0.05	-	0.3	0.01
Yam	79	434	0.06	-	0.7	0.08
Other Vegetables						
Brinjal	34	5	0.05	23	0.8	0.06
Ash gourd	15	-	0.06	5	0.4	0.01
Cauliflower	39	38	0.10	66	0.9	0.08
French been	26	221	0.08	14	0.3	0.06
Cucumber	14	-	0.03	7	0.2	0.02
Lady Finger	41	58	0.06	16	0.6	0.06
Pea	109	139	0.25	9	0.8	0.01
Pumpkin	28	84	0.06	2	0.5	0.04
Snake gourd	22	160	0.04	-	0.3	0.04

Source: NIN, ICMR, Hyderabad, 1999

5.5.1 Physical Methods

In the physical method, the maturity of the fruit is judged by visual observations or by simple methods. They are size, shape, colour, weight, specific gravity, firmness, juice content, total soluble solids (TSS), and produce holding strength by the pedicle of the plant.

Usually size and weight of individual fruit depends on several factors so they can be considered only when such factors are known. For ex. Cultivar, planting material, nutritive available, soil type and climatic condition effect the size and weight of individual fruit. Some fruits develop colour, angularity and their specific gravity changes with the maturity. In general fruit and vegetable when they attain maturity do not develop enough force required to detach them from plant. Table 5.3 provides some indices of maturity of fruits and vegetables.

Colour charts are used for determing the maturity of some fruits, which changes the colour on maturity like stone fruits, tomatoes and banana. Colour charts or photographs can be provided to the worker engaged in harvesting to make the process effective.

Firmness is measured as degree of softness of the fruit and measured by the penetrometer. After choosing an appropriate plunger, hold the fruit against firm surface. Press the plunger with the uniform speed till it punctures the fruit peel.

In some fruits like grapes, citrus, mango, muskmelon etc sugar is the main soluble solids in the fruit juices. Thus, total soluble solids (TSS) measured by the hand refractrometer can considered as index for degree of maturity of these fruits. In juicy fruits like citrus, juice content can be an index of maturity.

5.5.2 Chemical Methods

The fruit maturity is judged by the chemical analysis of the constituents. They are titrable acidity, TSS/acid ratio, sugar/acid ratio, starch content, tannin content etc. In many fruits acidity decreases with the maturity. It can be determine by titrating fruit juice with 0.1 normal sodium hydroxide and phenolphthalein as an indicator.

Some fruits acidity alone cannot be taken as index of fruit maturity. However, a ratio of TSS to acid provides better judgment. We have already read that TSS can be measured by hand refractrometer.

Sugar either free or as derivative play an important role in imparting taste, flavour and texture to the fruits. It is considered as reliable index of maturity of fruits. As the fruit ripens, its starch is partly converted into sugar. Thus, measurement of starch by colorimetric method or by iodine reaction method can also provide an index of maturity.

Table 5.3: Maturity indices for fruits and vegetables

Fruits/Vegetable	Maturity Indices/Characteristics
Mango	Specific gravity 1.01-1.02, fullness of checks and roundness of shoulders
Banana	Angularity to round shape change of colour in some cultivars

Citrus	TSS:acid =12
Grapes	TSS: acid=20
Apple	TSS 12; Firmness 7kg
Peaches/Pears	Colour change from green to yellow, TSS=12
Plums/ber	Skin colour change
Custard apple	Turning of skin as creamy white between segments
Pomegranate	TSS = 16
Brinjal	Glossy skin and seeds are not hardened
Cabbage	Solid
Carrot	Size
Brocoli/cauliflower	Compact flower
Cucumber/Gourd	Tender, before hardening of seed coat
Lady finger	Non-fibrous, tips of pods pliable
Onion	40-50% tops fall
Peas	Shining green, filled
Capsicum	Green and shining
Chilli (hot)	Dark red colour
Potato	Foliage get dried
Tomato	For processing : Red For medium distance market : turning stage (pink) For distant market : breaker stage (green ripe)

Source: Research compilation from different papers and reports of PHTS (Post Harvest Technology Subject)

5.5.3 Biochemical Methods

Evolution rates of carbon dioxide and ethylene are considered as the most reliable methods to judge the maturity index of the fruits. In the climacteric fruits, carbon dioxide evolution increased during ripening stage. Ethylene is considered as ripening hormone and is also a good indicator for judging maturity, suitability of storage and other end uses. However, for non-climacteric fruits their suitability has not been established.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why fruits and vegetables are called protective foods?

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2. Name the instrument used to measure the firmness of fruits and vegetables.

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3. Name the instrument used to measure total soluble solids of fruit juices.

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5.6 CULTURAL PRACTICES

Soil type and climate do affect the quality of the end produce. But these are not in the hands of the growers. The cultural practices like soil-water management, canopy management, fruit thinning, doze and time of mineral application chemical sprays, pest management, affect the quality and quantity of horticultural produce not only at the time of harvest but also during storage. It is difficult to analyze the effect of each one of them individually. Affect of cultural practices on citrus fruit is shown in Table 5.4.

Table 5.4: Cultural practices affecting the quality of citrus fruit

Cultural Practices	Size	Weight	Maturity	Rind thickness	Soluble solids	Acidity	Juice content	Ascorbic acid	Colour yellow
Excess irrigation	+	+	+	-	-	-	+		
Girdling	+	+			+	-	+		
Mineral Nutrition									
Nitrogen	-	-	-	+	+	+	-	-	-
Phosphorus	-			-	-	-	-	+	-
Potash	+	+	-	+	-	+	-	+	-
Magnesium	+	+			+	-	+	+	
Zinc	+				+		-	+	
Chemical Sprays									
Oil emulsion					-				-
Lead arsenate	-		+	+	+	-		+	
2,4-D	+	+	-	-	-	+			-
GA	-	-	+	+	-	+	-	+	

Source: Research compilation from different papers and reports of PHT (Post Harvest Technology Subject)

Blank space shows no information available

+ : indicates positive effect; increase, hasten, thick, hard, smooth or good flvaour

- : indicates negative effect; decreases, delays, thin, soft, rough and poor flavour

5.7 PRE-HARVEST TREATMENTS

It is well known that mineral content greatly affect the fruit quality at harvest and changes after harvest. Post harvest shelf-life is mainly dependent upon level of calcium in the fruit. Usually application of higher level of nitrogen, phosphorous and magnesium and lower level of potash and boron leads to calcium deficiency in fruits and reduces the post harvest shelf-life. Pre-harvest treatments of calcium delays ripening and senescence and improves the quality of produce. Low calcium content in tissues lead to physiological disorders such as : (i) bitter pit in apples ; (ii) cork spot in pears; (iii) end rot in tomatoes ; (iv) tip burn in lettuce and (v) hollow heart in potatoes.

Application of zinc and boron improves the mobility of calcium in the leaves and to the fruit. It increases firmness, soluble solids, organic acids, and ascorbic acid and reduces disorders. Chemicals used to extend the shelf life of fruits and vegetables are listed in Table 5.5.

Table 5.5: Chemicals and their schedule of pre-harvest application to enhance

Post Harvest Shelf-life of Horticultural Produce

Fruit/ Vegetable	Chemical & concentration	Time of application (Days before harvest)	Response
1. Apple	Boric acid (0.1-0.2%) silver-nitrate, 75 ppm	60 and 45 45	Improve calcium mobility Enhance shelflife
2. Mango	Calcium nitrate (1%) Or Calcium chloride (0.6%) Bavistin 0.1%		Enhances shelf-life Controls anthracnose and Stem end rot
3. Mango	Thiaphenate methyl 0.05% Gibberllic acid 10-15 ppm Phosphonomethylcin 5%	10	Post harvest losses Delayed ripening High TSS
4. Guava	Calcium 0.6%	20 and 10	Delayed ripening
5. Ber	Calcium compound 1.79/litre Ethereal, 750 ppm	10	Delayed fruit ripening Hasten maturity
6. Grape	Calcium nitrate 0.75%	10	Reduces weight loss & decay
7. Onion	Meleic hydrazide 2000-3000 ppm	15	Reduces sprouting during storage and reduces losses

Source: Research compilation from different papers and reports of PHTS (Post Harvest Technology Subject)

5.8 SAFE HARVESTING

Harvesting is an important unit operation in horticultural crop production. Though, it appears simple but it does require certain skills. Harvesting period is usually short. Improper harvesting may result in poor quality produce and also damage the plant. Therefore, the harvesting is further subdivided in following sections:

- Identification
- Clipping / Cutting / Picking
- Collection
- Do's and don'ts of Quality Harvest

5.8.1 Identification

Identification of properly mature fruits based on the parameters studied earlier i.e. size, shape, colour, acidity, TSS, firmness etc is the first most important task of the person engaged in harvesting.

5.8.2 Clipping / Cutting / Picking

Identified fruit which is separated from the plant is called clipping/cutting/picking. Improper harvest not only damages the produce but also causes injury to the plant. Manual method of harvesting includes holding the fruit, twisting it and pulling it. It damages the fruit as thumb impression and due to the pressure some times it injures the fruit near the pedicle and also plant stem. On such fruits mould growth is observed after 48-72 h. So they are not suitable for long distance transport.

Clippers and knives provide smooth cut with the desired length of pedicle. Long pedicle is likely to damage neighbouring fruits during transport. It is preferred to have as small a pedicle as possible. Some times fruits are not accessible. Pricking poles attached with collecting bags can be used without climbing on the tree. Tripod ladders could also be used, which are stable and person can reach the fruits.

5.8.3 Collection

In general harvested fruits are dumped on the ground. Where these fruits come in contact with soil. Impact by which it is dropped on the ground and microbes present in the soil contaminates the fruits. Therefore, harvested fruits are to be collected in cloth bags, put on shoulder. These bags are to be carefully unloaded in the plastic crates kept under shade. Plastic crates may be expensive in the beginning but they are reusable. They help in reducing post harvest damage during transport and provide sufficient ventilation to remove field heat. They can also be stacked easily.

5.8.4 Do's and Don'ts of Quality Harvest

i) Harvest as per the market need and proper maturity stage of produce.

ii) Use proper tool to harvest, bag-to collect and crate during handling.

iii) Containers used should be clean, smooth, free from rough edges.

iv) Avoid hand touching of the fruits.

v) Train pickers for harvesting, handling the produce.

vi) Keep produce free from soil contamination.

vii) Keep produce in shade.

viii) Harvest early morning or late evening as these are low temperature at that time.

ix) Field sorting and packing is to be promoted.

x) Cure the roots and tubers before storing.

5.9 POST HARVEST TREATMENTS

On-farm post harvest treatments are basically into two:

1. Removal of field heat by cooling
2. Disinfections of the produce

5.9.1 Pre-cooling

Cooling of fresh produce means removal of the field heat. You remember that in article 2.8.4 it was mentioned "harvesting/picking should be done in the early morning or late evening during low temperature". It is well proven that if the fresh produce temperature is lowered by 10^{o}C in first hour, its shelf life is doubled. You know fruits and vegetables are living. They respire if the temperature is more, their respiration rate increases. Thus, during handling it releases more heat and deteriorates the quality of the produce. The fresh produce can be cooled by:

- Natural cooling
- Forced air cooling
- Hydro cooling

Natural Cooling

The natural cooling is the simplest method in which harvested produce is to be kept in shade on a pucca floor or polyethylene sheet. It is the slowest method of cooling and sometimes time taken to remove the field heat is so high that spoilage of produce starts during cooling itself. Some people misunderstood this and kept the freshly harvested produce in cold room. It may cause harm to the produce as warm fresh produce releases water which when condenses and spoils the produce. Thus, such places should be equipped with good ventilation to remove the field heat.

Forced Air Cooling

Cold air is blown above the freshly harvested produce. It is many times faster than the natural cooling. It suits most of the fruits, which cannot be dipped inside the water for hydrocooling for i.e. strawberry, grapes etc. The main advantage of forced air cooling is that it not only carried heat librated but also carries the moisture evaporated from the fruits. The only disadvantage is if excess air is blown. Then loss of weight of fruit is high.

Hydro Cooling

It is the most effective method in which freshly harvested produced are dipped in cold water or cold water is sprayed over them. The advantage of this method is that it is fastest method of cooling and washing the produce. However, it requires more energy because surface water of the fruit is to be removed before packaging is done by forced aeration. The temperature of water should not cause cold injury or the shower pressure shouldn't damage the produce.

5.9.2 Disinfections of Produce

Fruit and Vegetables are exposed to nature, which is a vast ocean of microbial load. As long as they are on the plants, there resistance power is more. Once detached, the produce needs to be disinfected. The produce can be disinfected by treating with the hot water or chemicals (fungicides).

Hot Water Treatment

Most of the microorganisms and heat sensitive. Thus by dipping the produce for 1 to 5 minutes (depending on type of produce) in hot water (50-55^{o}C) checks the microbial load. In some of the produce time-temperature combination for disinfection is carried out this is given in Table 5.6. After the hot water treatment produce is kept in a cool room and gentle air is to be blown. It removes surface moisture and cools the produce.

The heat treatment temperature and time depends on the type of fruit/vegetables, and their microbial load. Care should be taken that it should not affect the quality of fruit.

Chemical and Fungicidal Treatments

Dipping in aqueous solution of some chemicals reduces the physiological loss in weight and microbial load and enhances the shelf-life of the fruit and provides uniform ripening. Some chemical treatments are given in Table 5.7.

Table 5.6: Hot water treatment to horticultural produce

Fruits/ Vegetables	Temperature (°C)	Time controls (sec/min)
Mango	52 °C 5 min	Controls anthracnose
Mango	46°C 65 min	Anthracnose and fruits fly
Citrus	50 °C 2 min	Enhances post harvest shelf-life
Capsicum	55 °C 12 ± 2 sec	Checks respiration, PLW and shriveling during storage. Enhances Post harvest shelf-life and capacity to with stand thermal stress.

Source: Research compilation from different papers and reports of PHT (Post Harvest Technology Subject)

Table 5.7: Post harvest applications of chemicals / fungicide

Fruit	Chemical / fungicide and doze	Treatment	Effect
Mango CV. Banganapally	Wax, 6%	1 min	Reduces PLW
Mango	Ethylene 10-100 ppm Ethepon/ Etheral 500 ppm	21-25°C for 12-48 h hot water	Uniform ripening and colour development
Mango	Calcium chloride solution less than 4%	Dipping	Delayed ripening
Banana	Waxol –12 Potassium permanganate	Dipping	Delayed ripening
Banana	Sulphur 0.1%	Pasting	Control crown fungi
Grape	Sulphur oxide fumes or 0.5% water spray	Fumigation	Reduces respiration, enhances shelf-life and control growth and spread of rot
Citrus	Waxing bavistin or GA_3-200 ppm or Cytokine 20 ppm	Dipping/spraying	Control spoilage, enhances shelf-life
Guava	GA 200 ppm	Sealed PLDE bags	Enhances shelf-life
Peaches	Potassium permanganate 1000 ppm	Paper soaked lined CFB	Enhances shelf-life
Apples	Calcium chloride 2-3%	Dipping	Helps in ripening
Cabbage	Alum 15% or lime powder at butt end	Treating	Controls Bacterial soft rot

Source: Research compilation from different papers and reports of PHT (Post Harvest Technology Subject)

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the physiological disorder occur in the potato and apples and its cause.

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2. List the steps of safe harvesting of horticultural produce.

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3. Why pre-cooling is essential in the fruits and vegetables?

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5.10 POST HARVEST MANAGEMENT

In our country the most (above 97%) of the horticultural produce is consumed as fresh. The post harvest handling involves movement of the horti produce from field to the dining table. This may be in bulk or retail. The better quality, produce fetches better returns. Therefore, the quality of produce is to be maintained by keeping a close eye on the movement of the produce. The steps involves are:

- Sorting
- Cleaning

- Trimming/chopping
- Waxing
- Grading
- Packaging
- Labelling
- Storage
- Transportation

5.10.1 Sorting

It is an important unit operation, which is advised to be carryout at the field itself. Removal of damaged, diseased, immature or over mature produce are to be rejected in the field. By removing them, the cost incurred in their transportation and handling can be saved. Moreover, these produce have higher respiration rate, so heat evolved by them is higher and very likely spoil the adjoining produce.

5.10.2 Cleaning

Fruits and Vegetables are exposed to the outer atmosphere. Thus, soil, dust and other impurities are adhered to their peel. Cleaning may be dry or wet (washing) is required to remove the adhered impurities from the produce. It helps in improving the appearance and also cools the produce. Some fruits, whose peel is very soft do not require washing with water like strawberry, kiwifruit, avocados etc. For them gentle air is blown to clean them. Fruits whose natural wax is removed during washing is also not washed with the water.

Spray washing or dipping in a tank with gentle brushing is done to remove adhered impurities. The choice of brushing mainly depends upon type of commodity and contamination.

Hygienic and sanitary conditions are to be maintained to check the spreading of disease and microbial load of washing water. Water may be treated with chlorine (100-150 ppm) to control spores.

5.10.3 Trimming

Some crops contain non-edible parts/excess leaves with the produce. These unwanted portion not only creat an unnecessary bulk but also lead to microbial infection and water loss. Thus such produce are to be trimmed/detopped before storage and handling.

5.10.4 Waxing

Food grade waxing of green vegetable like cucumber, tomatoes and fruits like citrus, apples, peaches is a common practice. It helps in reduction in loss of water during handling and marketing and enhances the shelf-life. Wax coating is done by mist applicator on a moving belt. After wax coating the produce their surface has to be dried before further handling.

5.10.5 Grading

Grading of the produce based on size or colour often fetches premium price in the market. Uniformly graded material provide better appearance and they are easy to pack. Experienced person generally does the grading in India manually.

However, for round produce, size base grades and for some specific fruits weight base mechanical graders are available in different capacity.

5.10.6 Packaging

The main purpose of packaging is to protect the produce during handling, transportation and storage from deterioration due physical, chemical or biological factors. Horticultural produce are highly perishables. After grading, the produce have the uniform maturity and requirement for safely against mechanical injury, and physiological activities like respiration. The package should have the following features:

- ✓ It should have sufficient mechanical strength which can withstand dead load during transportation (including impact and vibrations).
- ✓ It should be well aerated to remove respiration heat and humidity.
- ✓ It should be attractive and economical.

In general horticultural produce are handled through wooden cartons, corrugated fiberboard boxes and plastic crates. To avoid damage produce by touching each other liners/fillers are used of corrugated fiberboard or newspapers or grasses. Polyethylene lines are used to increase the humidity and decrease the water loss from the fruits.

5.10.7 Labelling

Fruits and Vegetables are delicate. Labelling of packages helps the people handling them during loading/unloading, stacking during storage or transportation. The label should contain information regarding maximum stack height, storage temperature and relative humidity conditions, date of packing and best before use. It should also have name of the commodity, its net weight and address of the producer.

5.10.8 Storage

In general fruits and vegetables are stored at low temperature and high humidity. It helps in reduction in respiratory rate and enhances the shelf-life. Appropriate storage conditions for storage of different horticultural produce is given in Table 5.8.

For temporary/transit storage for 1-day produce can be kept in the evaporating cool chamber where humidity is 90-95% and temperature is 10-15 ^{o}C lower than the atmospheric temperature.

Horticultural produce can be stored in modified atmosphere package (MAP) or controlled atmosphere (CA). In this storage, the oxygen concentration is reduced (in general below 5%) and carbon dioxide concentration is increased (3 to 7%). It helps in enhancing the shelf life and maintaining the quality for longer period.

Table 5.8: Storage conditions for fruits and vegetables

Produce	Temperature (°C)	Relative Humidity (%)	Storage life
Fruits			
Apples	1-2	90-95	12 months
Grapes	1-2	90-95	1 month
Citrus	3-8	80-90	3 month
Peaches	1-5	80-90	2 weeks
Pears	1-5	90-95	4-6 weeks
Strawberry	2-5	95 +	1 week
Banana	12-15	80-85	2 week
Mango	10-15	85-90	3 week
Vegetables			
Cabbage	0-2	95-98	3-6 months
Cauliflower	0-2	90-95	4-6 weeks
Cucumber	10-13	95	2 weeks
Brinjal	10-12	90-95	1 week
Onion / garlic	0 to 5 or 25-28	65-70	6 months
Ginger	10-13	65	6 months
Okra	7-10	90-95	10 days
Pea (Green)	0	95 +	2 weeks
Potatoes	4-8	90-95	10 months
Tomatoes	12-15	90-95	1-2 weeks

Source: Food Preservations by modified atmosphere, By Calderon amnd Golan, CRC Press

5.10.9 Transportation

The refrigerated vans are the best method for transporting the produce from one place to another. However, it is not common practice in our country. Therefore, open vans with system of air movement to remove the respiratory heat should be practiced. In the van stacks should be arranged uniformly with thick cushioning pads (straw) to absorb the shocks.

5.11 PROCESSING OF FRUITS AND VEGETABLES

Fresh fruits and vegetables contain 70% or above water on wet basis. Large amount of water and respiration trigger the chain reactions of microbial activity. The purpose of processing is to develop value added products which are stable. The stability can be obtained by:

- Reducing the chemical potential of water by
  - application of heat
    - → Pasteurization
    - → Canning
    - → Dehydration (Drying & reducing a_w)
    - → Concentration
  - addition of solute
    - → Jams, jellies, marmalades
    - → Salting
- Fermentation
  - → Pickling
  - → Beverages (Fermented & non fermented)

5.11.1 Reducing the Chemical Potential of Water

Water present in the fresh produce can be removed by dehydration or addition of solutes which can strongly bind the water and not allow it to take part in deteriorating reactions.

a) Dehydration

It is the simplest and the oldest method to remove the free water from the produce and make it shelf stable. The quality of dehydrated materials depends upon the method of drying, temperature and rate of drying. Natural sun drying is the oldest practice but it provides uneven drying, sometimes gets contaminates from the atmosphere. Therefore, indirect sun drying (solar dryer), or the dryers operated with electricity, diesel or gas can be used to develop good dehydrated product.

Prior to drying, the product is to be blanched and exposed to sulphur fumes which helps in drying and maintaining the colour and flavour of the dried product Table 9 provides the temperature required for drying different produce. Excess temperature may cause loss of nutrients and or caramalization of sugar. Dried product can be stored for few months without refrigeration.

Table 9: Drying air temperature and time required for drying for different produce

Produce	Drying air temperature (°C)	Time required for drying (h)
Apple	50-55	6-8
Banana	50-55	6-8
Grapes	50-55	24-48
Mango (unripe)	50-55	24-36
Garlic	55-60	6-8
Onion (slices)	50-55	8-12
Pea	55-60	12-18
Green chilli (cut)	55-60	4-5
Spinach	55-60	4-5
Cauliflower	55-60	8
Potato chips	50-55	4.

b) Solute Addition

It is well known that by adding sugar or salt, fruits and vegetables can be preserved longer. These chemicals bind the water present in the food and thereby prevent the water to take part in deteriorating reactions. Jams, Jelly, fruit bar, preserves are sugar-preserved products whereas pickles are salt preserved.

The products can be made of intermediate moisture content (18-35%) by partially drying them in air. Such products retain more nutrients, colour, flavour and require less energy in product development.

5.11.2 Fermentation

It is an aerobic/partial anaerobic oxidation process. During the process desirable microorganisms are produced. Some of the useful products from fermentations are acids and alcohols.

The list of some products prepared from fruits and vegetables are given in Table 10.

Table 10: List of some products prepared from fruits and vegetables

Produce	Existing Products	Newer Products
Green Mango	Pickle, chutney, dried slices powder	Drink, juice, concentrate
Ripe Mango	Canned slices, pulp, juices nectar, jam, bar	Frozen slices, concentrate wine, vinegar
Banana (unripe)	Chips	Defatted chips and powder
Banana ripe	Pulp, figs	Powder, bar
Grapes	Raisins, juice, wine	Concentrate
Guava	Jelly, juice, nectar	Bar, powder
Apple	Juice, jam	Juice concentrate, bar dehydrated slices
Oranges	Juice	Juice concentrate, segments
Papaya (raw)	Tuttifruity	Papain
Papaya (ripe)	-	Pulp, slices
Aonla	Preserve, pickles, juices power	Salted and sweet segments
Pea	Dehydrated, brive solution canned	-
Carrot	Juice, pickle, canned	Dehydrated
Onion	Dehydrated slices powder	-
Tomato	Puree, sauce, drink	Powder
Chilli	Dehydrated, powder, pickle	Paste

5.12 BY PRODUCT UTILIZATION

Fruits and Vegetable processing industry is called as sunrise industry in the country. During the processing more than 50% of the material goes as waste. Thus, waste disposal and its utilization is a challenge.

The fruit industry waste contains mainly cellulose, starches, pectins, vitamins, minerals and other micronutrients. These waste can be used for oil, animal feed, fuel, manure and some value added products like pectins, tartaric acid, citric acid etc. Table 11 gives the different waste material and their possible value added products.

Table 11: By-products of horticultural produces and their possible uses

Produce	Waste	Possible uses
Mango	Peel, stone, kernel trimmings	Starch, fat, vineagar kernel flour, animal feed, manure, besides medicinal use to cure diarrhoea, piles etc.
Guava	Seed, core, pomace	Ethanol, oil from seeds, pectine, animal feed
Grapes	Stem, pomace, peel, seeds	Seed oil, cream of tartar, tannin, wine fertilizer
Citrus	Peel, seed, pomace	Molasses, peel oil, cosmetics, soap, textile, pectine, wines, citric acid

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why sorting at farm level is preferred?

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2. How sanitary conditions are maintained during washing?

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3. How waxing of fruits and vegetables enhances shelf life?

4. List the properties of ideal fruit package.

5. "Moisture is torture to fruits". Explain?

6. Why blanching is done prior to drying?

5.13 TECHNO-ECONOMIC FEASIBILITY

Some product base techno-economic feasibility has been given. The plant capacity can be enhanced or some other products can be taken up with the same machines.

5.13.1 High Moisture Products like Fruit Jam, Jelly, Preserve, Canned Slices etc.

Plant capacity	100 kg/day
Land	20 × 25 m
Constructed area	12 × 15 m
Cost of machines	Rs. 5,00,000/-
Rolling capital	Rs. 75,000/-
Quality control klaboratory	Rs. 1,00,000/-
Essential utilities	Food grade water Liquid waste water disposal system Electric power
Other utilities	Assured quality raw material Approachable Telephone
Rate of return	25% +
Break even point	45%

5.13.2 Intermediate Moisture Products like Raisin, Figs, Fruit Bar etc.

Plant capacity	100 kg/h
Land	20 × 25 m
Constructed area	10 × 15 m
Cost of machines	Rs. 6,00,000/-
Rolling capital	Rs. 1,20,000/-
Quality control laboratory	Rs. 1,00,000/-
Essential utilities	Food grader water Electric supply Liquid waste disposal system
Other utilities	Telephone Quality raw material Approachable
Rate of return	17% +
Break even point	About 60%

5.13.3 Dehydration Plant

Plant capacity	1000 kg/day
Land	20 × 25 m
Constructed area	15 × 15 m
Cost of machines	Rs. 10,00,000/-
Rolling capital	Rs. 2,00,000/-
Quality control laboratory	Rs. 1,00,000/-
Essential utilities	Food grade water Electric supply Solid and liquid effluent disposal system
Other utilities	Telephone Quality raw material Approachable
Rate of return	21%
Break even point	62 % (about)

5.13.4 Tomato Processing (Juice, Sauce, Ketchup, Puree)

Plant capacity	1000 kg /day
Land	20 × 25 m
Constructed area	12 × 15 m
Cost of machines	Rs. 6,00,000/-
Rolling capital	Rs. 1,00,000/-
Quality control laboratory	Rs. 1,00,000/-
Essential utilities	Food grade water Quality raw material Effluent disposal system
Other utilities	Electric power, approachable , telephone
Rate of return	23 %
Break even point	65%

5.13.5 Fruit Juice, Concentrates and Beverages

Plant capacity	500 kg/day
Land	20 × 25 m
Constructed area	15 × 15 m
Cost of machines	Rs. 10,00,000/-
Rolling capital	Rs. 125,000/-
Quality control laboratory	Rs. 75,000/-
Essential utilities	Food grade water Effluent disposal systems Electric power
Other utilities	Approachable Assured quality raw material Telephone
Rate of return	35%
Break even point	50%

5.14 LET US SUM UP

Fruits and Vegetables are of immense significance to man. Their nutrition, taste helps in good health in a human being. In the present scenario where horticultural production has increased many folds in last few decades but due to poor post harvest management losses has also increased. It is estimated that losses in fruits and vegetables amounts to be Rs. 67,000 crores annually. The main places where losses or damage initiate in the horticultural produce are on the plant itself, harvesting time, handling and storage. These losses can be minimized by pre and post harvest treatments and post harvest management. Surplus produce can be diverted for the processing, which will also create employment.

5.15 KEY WORDS

Climacteric Fruits : Those fruits that develop total senescence sometime after the harvest during storage. Fruits having higher respiration rate, produces of carbon dioxide and ethylene more than the non-climacteric fruits.

Pentrometer : Instrument to measure firmness of produce

Refractometer : Instrument to measure total soluble solids in the produce

Sorting : Removal of damaged, diseased, immature or over mature produce.

Blanching : Heat treatment given to the produce prior to the drying to inactivate enzymes, stabilize product and facilitate easy drying.

Sulphiting	:	Soaking (30 minutes) in the solution of potassium meta bisulphite prior to drying to maintain the colour.

5.16 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Any three fruits: Banana, Mango, Papaya, Sapota
   Any three vegetables: Cauliflower, Pea, Okra

2. Reasons for huge post harvest losses are:

   i) Poor infrastructure facility at the production site.
   ii) Poor post harvest handling and transport facility.
   iii) Less awareness about safe harvesting, sorting and grading at farm level.

3. Reasons for poor farm yield compare to International benchmark are:

   i) Poor planting material
   ii) Unplanned farm management practices.

Check Your Progress Exercise 2

1. Fruits and vegetables are major source of nutrition (minerals and Vitamins) so they are called protective foods.

2. Penetrometer

3. Refractometer

Check Your Progress Exercise 3

1. In Apple – bitter pit
   In potato – hollow heart
   Due to low calcium content – in tissue

2. Steps of safe harvesting are:

   i) Use proper tool to harvest, bag-to collect and crate during handling
   ii) Containers used should be clean, smooth, free from rough edges
   iii) Avoid hand touching of the fruits
   iv) Keep produce free from soil contamination
   v) Keep harvested produce in shade

3. Fruits and vegetables respire and release the heat. The rate of respiration is high at higher temperature. It reduces the shelf life of the produce. So they are cooled.

Check Your Progress Exercise 4

1. Sorting at farm level helps in reducing the cost incurred in the transporting and handling of unwanted produce. Moreover, damaged and immature produce respire more and release more heat. Thus, it may spoil other adjoining produce.

2. Sanitary conditions can be maintained by treating with water containing 100 –150 ppm chlorine.

3. Waxing of perishables reduces the rate of respiration and checks water loss thus, it enhances the shelf life of the produce.

4. Ideal fruit package should have

   i) Sufficient mechanical strength to withstand dead load during transportation. (Including impact and vibrations)

   ii) Good aeration to remove respiration heat and humidity.

   iii) Be attractive and economical.

5. Moisture in the fruits triggers the chain reactions of microbial activities, so moisture is a torture.

6. Blanching helps in drying by evacuating the air from pore spaces, and stabilize the product from microbial load.

5.17 SOME USEFUL BOOKS

1. Chakraverty, A., Mujumdar, A.S., Raghavan, G.S.V. and Ramaswamy, H.S. (2003) Hand Book of Postharvest Technology of Cereals, Fruits, Vegetables, Tea and Spices. Marce; Dekker Inc., New York.

2. Anonymous (1990) Home Scale Processing and Preservation of Fruits and Vegetables. CFTRI Publications, Mysore.

3. Lal, G., Siddappa, G.S. and Tandon, G.L. (1986) Preservation of Fruits and Vegetables. ICAR New Delhi.

4. Chadha, K.L. (2001) Hand Book of Horticulture. ICAR, New Delhi.

5. Kalia, M., Sood, S. (1999) Food Preservation and Processing. Kalayani Publishing, Ludhiana.

6. Rao, M.A. and Rizvi, S.S.H. Engineering Properties of Foods. Marcel Dekker Inc. New York.

7. Earle, R.L. Unit Operations in Food Processing. Pergamon Press, New York.

8. Bhatti, S. and Varma, U. (1997) Fruits and Vegetables Processing. CBS Publishers and Distributors. New Delhi.

9. Ranganna, S. (1995) Hand Book of Analysis and Quality Control for fruits and Vegetables Products. 2nd Edition. Tata McGraw Hill Co. Ltd., New Delhi.

10. Srivastava and Sanjeeb Kumar (1994) Fruits and Vegetables Preservation Principles and Practice. International Book Distribution Co. Lucknow.

UNIT 6 DAIRY, POULTRY, MEAT AND FISHERIES

Structure

6.0 OBJECTIVES

After reading this unit, you should be able to:

- state the present production status and importance of livestock products including fisheries in national economy;
- enumerate important value added products from milk;
- indicate steps for clean milk production;
- give the basic features of poultry management and preservation of eggs and meat;
- indicate important preservation and processing techniques for meat;
- differentiate between the culture and marine fisheries; and
- outline the principles of preservation and processing of fish.

6.1 INTRODUCTION

Animal husbandry, dairying and fishery activities along with agriculture have been an integral part of human life since the beginning of civilization. Man has been domesticating animals either for food or for cultivation and transport. These domestic farm animals or livestock such as, dairy cows/ buffaloes, goat, sheep, beef cattle, horses, pigs, chicken and turkeys play an important role in the socio- economic life of India. Livestock products play a pivotal role in improving the livelihood of a large number of people by providing food products and by-products for human utility. Besides providing high quality foods such as milk, eggs, meat, fish etc; the livestock sector provides employment to millions of rural farmers and people engaged in secondary and tertiary business related to it. The unit gives a profile of important livestock products in reference to food processing industries.

6.2 PRODUCTION AND ECONOMIC IMPORTANCE

6.2.1 Production

India has vast resource of livestock and poultry. India ranks first in respect of cattle and buffalo, second in goat, third in sheep and seventh in poultry population in the world. The country has 57% of the world's buffalo population. Table 6.1 gives the livestock population details and a profile of livestock products, i.e. milk, eggs, meat and fish is given in Table 6.2, 6.3 and 6.4.

Table 6.1: Livestock population

(million nos.)

Sl. No.	Species	Livestock census		Growth rate (%) 1997 over 1992 annual (comp.)	
		1992	1997		
1.	Cattle	204.58	198.99	-2.79	-0.56
2.	Buffalo	84.21	89.91	6.77	1.32
3.	Sheep	50.78	57.29	12.82	2.44
4.	Goat	115.28	122.71	6.45	1.26
5.	Pigs	12.79	13.29	3.91	0.77
6.	Others	3.22	3.28	1.86	0.37
Total Livestock*		470.86	485.36	3.08	0.61
7.	Poultry	307.07	347.11	13.04	2.48

** - excludes pack animals, yaks and mithuns*

Source: Annual Report (2003-04), Dept. of Animal Husbandry & Dairying, Ministry of Agriculture.

Table 6.2: Production and availability of milk and eggs

Particulars	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05
Milk (million tones)	72.1	75.4	78.3	80.6	84.4	86.2	88.1	91.00
Per capita availability (gms/day)	207	213	217	220	225	230	231	232
Eggs (Million numbers)	28689	29476	30447	36632	38729	39823	40403	41000
Per capita availability (nos./head/ annum)	30	30	32	36	38	39	40	41

Source: Compiled from Basic Animal Husbandry Statistics 2004, Dept. of Animal Husbandry & Dairying

Table 6.3: Meat production – 1997 to 2003

(in 000 Tons)

Year	Beef & Veal	Buffalo Meat	Mutton & Lamb	Goat meat	Pig meat	Poultry meat	Total Meat
1997	1378	1403	222	458	533	630	4626
1998	1401	1380	226	462	543	710	4721
1999	1421	1398	228	466	560	821	4894
2000	1442	1421	229	467	578	1081	5218
2001	1452	1428	230	469	595	1251	5426
2002	1463	1443	233	470	613	1401	5622
2003	1490	1471	234	473	630	1600	5898

Source: Compiled from Basic Animal Husbandry Statistics 2004, Dept. of Animal Husbandry & Dairying

Table 6.4: Production and export of marine products

Year	Fish production (million tonnes)			Export of marine products	
	Marine	Inland	Total	Quantity ('000 tonnes)	Value (Rs. crore)
1950-51	0.5	0.2	0.7	20	2
1960-61	0.9	0.3	1.2	20	4
1970-71	1.1	0.7	1.8	40	35
1980-81	1.5	0.9	2.4	80	235
1990-91	2.3	1.5	3.8	140	893
2000-01	2.8	2.8	5.6	503	6296
2001-02	2.8	3.1	5.9	458	5815
2002-03	3.0	3.2	6.2	521	6793
2003-04 (P)	3.0	3.4	6.4	412 (P)	5739

Source: Economic Survey (2004-05)

Requirement: The per capita animal protein availability is about 10 grams as against minimum requirement of 20grams (from milk 10g, meat 4g, fish 4g, egg 2g). The estimated demand for the present population would be milk 104 million tonnes, meat 7.7 million tonnes, fish 7.7 million tonnes and eggs 4.6 million tonnes (104 million number). A significant gap exists between the requirements and production.

Milk Production: India continues to be the largest producer of milk in the World. The milk output during 2003-04 was anticipated to be 88.1 million tonnes and is expected to reach the level of 91.00 million tonnes during 2004-05. The per capita availability of milk is also expected to increase to 232 g per day during 2004-05 from 207 g per day in 1997-98.

Egg Production: Poultry development in the country has shown steady progress over the years. The current production of eggs is estimated to about 41.00 billion (in numbers) during 2004-05. Currently India ranks fifth in egg production in the World.

Fish Production: There has been significant growth in fish production in the country in the recent years. India is now the third largest producer of fish in the world, and second largest producer of fresh water fish in the world. During the year 2002-03, the total fish production was 62.00 lakh tonnes comprising 30.00 lakh tonnes of marine fish and 32.00 lakh tonnes of inland fish. The fish seed production during the year 2002-03 was 16,333 million fry. Fish is a source of cheap animal protein and current per capita consumption of fish in India is around 9 kg per annum as compared to 11 kg recommended by World Health Organization (WHO).

Meat and Meat Products: Though the country has a good livestock population yet most animals are not bred/ reared in industrialized or scientifically controlled methods for meat production, which is reflected by a generally low annual slaughter rate across all species except pig. Most of the production of meat and meat products continues to be in unorganised sector. The share of bovine meat in the total meat production is about 60% as against small ruminants (sheep and goats – 15%), pigs (10%) and poultry (12%). There are about 3,600 licensed slaughter houses operating in the country, most of them being run and maintained by local municipal bodies. Overall, the scenario is: abattoir management is poor, technologies employed are out of date and hygiene and sanitary conditions are not perfect. As per FAO data the per capita / year meat consumption is 5.2 kg.

6.2.2 Economic Importance

Employment Generation: Animal Husbandry sector provides large self-employment opportunities. According to National Sample Survey Organization's latest survey (1999-2000), the estimate of employment in animal husbandry sector was 11 million in principle status and 8 million in subsidiary status, which is 5% of the total working population. Women constitute 71% of the labour force in livestock farming. Poultry provides employment to about 1.5 million people. The fisheries sector provides employment to over 11 million people. About 0.5 million women are employed in pre and post harvest operations in marine sector.

Value of Output: According to estimates of the Central Statistics Organization (CSO), the value of output from livestock and fisheries sectors together was about Rs. 1,86,094 crores at current prices during 2002-03 (Rs.156, 080 crores for livestock sector and Rs. 30,014 crores for fisheries). The livestock and fisheries sectors contributed 6.5 percent of total GDP(5.4 percent from livestock and 1.1. percent from fisheries) in 2003-03.

Export Earnings: Total export earnings from livestock, poultry and related products were Rs. 4734 crores in 2003-04. Out of the total exports, leather sector accounted for Rs. 2568 crores in value terms.

Export Potential of Marine Products: There has been steady growth in the export of fish products. During 2001-02, the country exported 4.58 lakh tonnes of marine products, which resulted in export earning of Rs. 5815.00 crores. Efforts are being made to boost the export potential through diversification of products for export. The country has now also started export of frozen squid, cuttle fish and variety of other finfishes. During 2002-03, the country has exported 5.21 lakh tonnes of marine products valued at Rs.6793.05 crores.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give the milk production and per capita availability of milk for the year 2002-03.

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2. Give the cattle and buffaloes population as per 1997 livestock census.

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3. List the economic importance of animal husbandry sector.

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6.3 DAIRY

We know that the milk is the lacteal secretion of the mammary glands of animals. Milk provides both energy and the building material necessary for growth. It also contains antibodies which protect the young animals against infection. In short, milk is a complete food in itself and nature has designed it as a food for the young ones during the first period of life. Let us know more about milk.

6.3.1 General Characteristics of Milk

The principal constituents of milk are water, fat, proteins, lactose (a type of sugar) and minerals (salts). Figure 6.1 shows the important constituents of milk in brief.

The milk of different species, although containing- the same constituents in general, varied in composition and properties in minor ways. Table 5 gives the composition of milk of a few mammals. Milk constituents are divided mainly into three groups namely, water, fat and solid-not-fat (SNF). Milk contains on an average 87 per cent water, 3.9 per cent fat, 4.9 per cent lactose, 3.5 per cent protein and 0.7 per cent minerals, vitamin and other constituents. Milk of ruminants like cow, buffalo and goat is ideally suited for human consumption and meet the basic dietary requirements of human beings.

Table 6.5: Average composition of milk from various species

Species	Constituents %					
	Fat	Proteins	Lactose	Ash	Total Solids	Water
Cow	4.0	3.4	4.6	0.74	13.64	86.36
Buffalo	7.3	3.8	4.9	0.78	16.78	83.22
Goat	4.0	3.7	4.5	0.85	13.05	85.95
Sheep	6.2	5.2	4.7	0.90	17.00	83.00
Camel	3.0	3.9	5.4	0.74	13.04	86.96
Human	3.5	2.0	6.8	0.30	12.60	87.40

Please incorporate the concept and role of co-operatives in milk production following account may help:

In India 'White Revolution' was brought due to operation Flood, largest dairy project for increased milk production in world. The key role in its success was played by "Co-operatives" a concept introduced by Dr. V. Kurien, father of white revolution small co-operatives at village level that involved the participation of farmers (milk produces) and collection centre (processors) was mutually helpful. Today almost all states have 'Milk Co-operatives' with AMUL (Anand Milk Producers Union Ltd.) becoming a global brand.

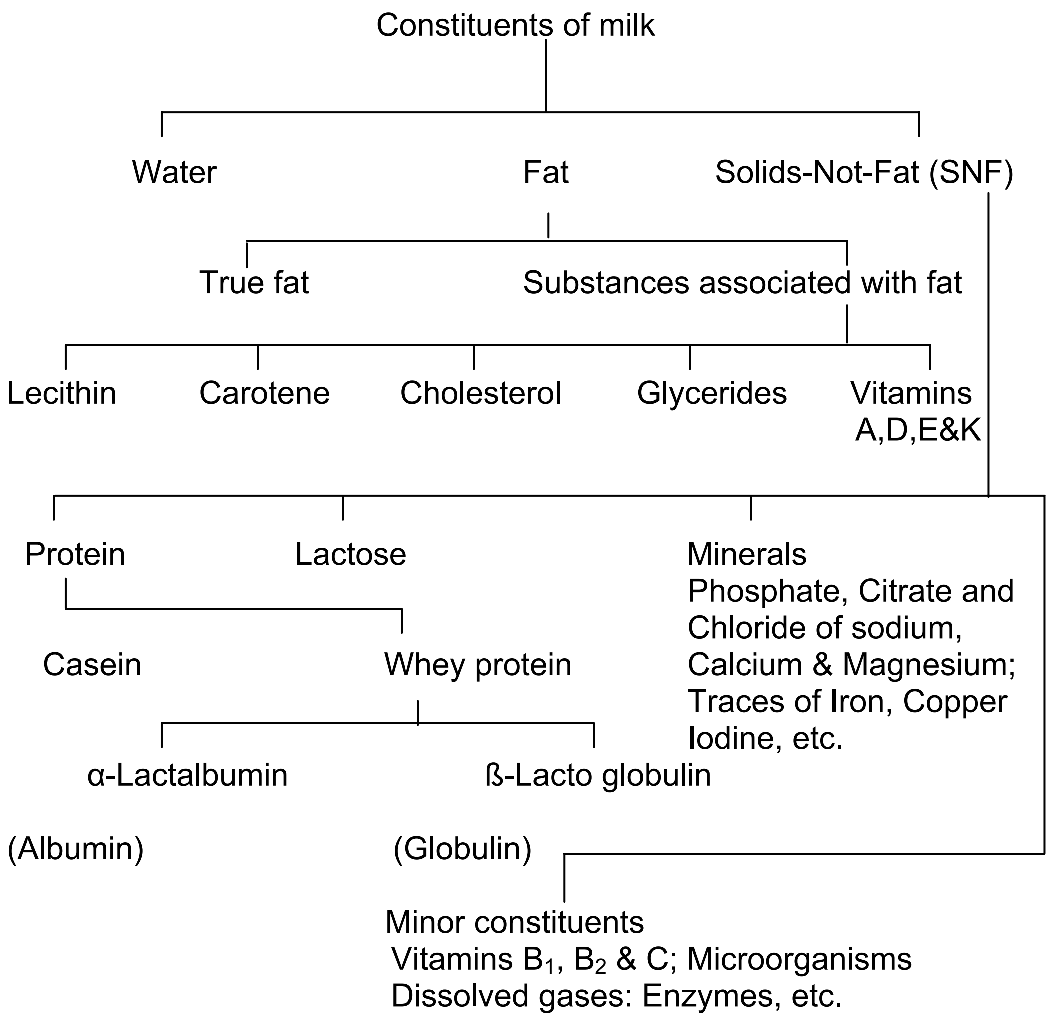

Figure 6.1: Milk constituents

6.3.2 Nutritional Importance of Milk

We know that the milk is recognized as almost an ideal food. It has high nutritive value. It supplies body- building proteins, bone- forming minerals and health giving vitamins. Lactose and milk fat furnish energy. Besides supplying certain essential amino acids and fatty acids, it contains the nutrients in an easily digestible and assimiliable form. All these properties make milk an important food for pregnant mothers, growing children, adolescents, adults, invalids, convalescents and patients alike. The nutritional importance of milk is significant with reference to our country as large population is vegetarian and for them milk & milk products are the only source of animal proteins. Besides, human milk has immunoglobuling, lactoferried, lysozyme and bifidus factor. These Bioprotective attributes make it a perfect food for infants. It's been clinically established that breast fading is best for infants.

6.3.3 Clean Milk Production

Milk is virtually sterile in the udder of a healthy animal. Milk once secreted becomes the target for contamination during milking, milk handling, transport and storage. The degree of infection and the composition of the bacterial population depends on the cleanliness of the animal's environment and the cleanliness of the new surface with which the milk comes into contact, e.g., the pail or milking machine, the strainer, the tanker or the tank and agitator. The bacteria can also get into the milk via the milker, the animal, the litter and the ambient air. Initially high bacterial counts and rapid growth of microorganisms will badly affect the keeping quality of the raw milk and the quality of products manufactured from such milk. Milk contaminated with pathogenic bacteria may be harmful to human health. Therefore, all possible measures should be taken to limit the contamination of milk and to prevent further bacterial growth. The quality aspects are gaining importance and emphasis is on the Clean Milk Production (CMP). The important steps for clean milk production are:

i) Clean and healthy animals: The cow's body especially the udder, should be washed and brushed before milking. Diseased animals should be kept separately.

ii) Clean Housing: Sheds, mangers, paddocks, water trough, floor should be clean and there should be good drainage.

iii) Fly proof milking parlour.

iv) Disease-free environment: milker with clean habits (nails well trimmed).

v) Clean Utensils, Milking pails.

vi) Clean water.

vii) Clean milking: Before milking, clean the udder with a cloth dipped in antiseptic solution such as potassium permagnate; wetting of hands with milk should be avoided.

6.3.4 Basic Milk Processing

Milk after being received at dairy plant is subjected to various unit operations. A few basic processing operations to which the milk is subjected are given here.

Reception and storage of milk : Each milk processing plant or chilling centre where milk is received in raw or chilled condition, requires a separate area for milk reception, commonly known as Raw Milk Reception Dock (RMRD). Milk is received at the dock either in cans directly from the producers / collection points or in insulated tankers from the chilling centres. The steps involved in the process are given in Figure 6.2.

Steps involved in Milk Reception at the Dock (RMRD)

In cans	**In tankers**
1. Unloading	1. Weighing
2. Grading	2. Grading
3. Weighing	3. Sampling
4. Sampling	4. Unloading
5. Dumping	5. Cleaning of tankers
6. Cleaning of cans	

Figure 6.2

The milk is chilled as early as possible in order to check the growth of organism present and maintain the keeping quality of milk. The chilled milk is stored in storage tanks or silos (large storage vertical tanks).

Milk separation: The process of separating out cream from milk is known as separation. It is based on the principle of difference in specific gravity between the fat (0.90-0.93) and the serums or solid-not-fat (1.027-1.036). This can be done either by gravity or by applying the centrifugal force. The dairy plants use 'Centrifugal Cream Separators' in which centrifugal force is applied to enhance rate of skimming, i.e. separating force is multiplied many times than that of gravity and the separation takes place more completely and instantaneously.

Pasteurization: Pasteurization is a process applied to a product with an object of minimizing possible health hazards arising from pathogenic micro-organisms associated with milk by heat treatment, which is consistent with minimal chemical, physical and organoleptic changes in the product. The term pasteurization as applied to market milk today refers to process of heating every particle of milk to at least 63° C (145° F) for 30 minutes or 72° C (161° F) for 15 seconds (or the temp-time combination which is equally efficient) in an approved and properly operated equipment. After pasteurization milk is immediately cooled to 5° C (41° F) or below. LTLT (Low temperature long time) is suitable for small quantities ranging from 200-1000 litre requiring low initial cost of production. HTST (High temperature short time) treatment is ideal for large scale handling of 5000 litres per hour (LPH) or higher. The complete process of preheating, heating, holding, pre-cooling and chilling is completed in a plate type heat exchanger mounted on a compact frame with inter connected sections to make the process continuous. Phosphatase test is carried out to determine whether milk has been properly pasteurized or not.

6.3.5 Milk Products

We know that milk is a rich source of nutrients and is an essential part of diet. Milk is a unique biological fluid which can be dehydrated, concentrated, coagulated, fermented and fractionated into a vast range of milk products. The popularity and consumption of milk products is constantly increasing in our country. Nearly, 50% of the total milk production is converted into various milk products. The focus is being given to value addition and international quality assurance to the indigenous dairy products as tremendous potential has remained untapped. A profile of few popular indigenous and western products is given here.

Butter: A fat rich dairy product obtained from churning milk, cream or curd and working the grains thus obtained into a compact mass. The butter making process involves a number of stages. Churning is the key step and it involves giving violent medium agitation which breaks the emulsion of fat in serums and induces the clumping of fat globules. It is a perishable product, and therefore, it should not be stored longer than necessary. For short period butter can be stored at 4° C but if longer storage is involved it must be stored at –21 to –29° C.

Concentrated and Dried Products: Drying the milk is an efficient method of preservation. In addition, drying also greatly reduces the volume of milk, which is an advantage for long distance transportation and extended storage. Alternatively, only part of the water can be removed from the milk and water activity is further decreased artificially increasing the amount of dissolved solids. This is done by dissolving sugar in a milk concentrate. Accordingly, on the industrial scale milk is preserved by drying or evaporation. The representation composition of these products is summarized in Table 6.6.

Table 6.6: Composition of preserved milk products

Product	Fat%	Milk solid not fat %	Sucrose (%)	Water (%)
Milk powder				
Skim	1	95.5	–	3.5
Whole	26.5	71.0	–	2.5
Evaporated Milk				
Unsweetened	8	18	–	74
Sweetened	8	20	45	27

Cheese: It is defined as a product made from the curd obtained from milk by coagulating the casein with the help of rennet or a similar enzyme in the presence of lactic acid produced by adding starter culture and from which part of the moisture (whey) has been removed by cutting, cooking and pressing. The concentrated solids thus obtained are shaped in a mould and then ripened by holding it at suitable temperature (8-10° C) and humidity. There are many varieties of cheese in the world today that are differentiated by thousands of name. Moisture content of cheese serves to distinguish various categories such as hard, semi-hard, and soft. Cheddar cheese, processed cheese, mozzarella and cottage cheese are quite popular in our country.

Frozen Dairy Products: Ice-cream is a popular frozen dairy product made by rapid freezing of pasteurized mix with agitation to incorporate air and ensure uniformity of consistency. As per PFA definition, the product should contain not less than 10% milk fat, 3.5% milk protein and 36% total solids. It may contain permitted stabilizer and emulsifier not more than 0.5%.

Khoa: *Khoa* or *Mawa* is an important traditional milk product of India. It is prepared by partial desiccation of cow or buffalo or mixed whole milk in an open fire. It is used as the base in several milk sweets viz. *burfi, kalakand, peda, milk cake, gulab jamun,* etc. As per PFA rules, the khoa is the product obtained from cow or buffalo (or goat or sheep) milk or a combination thereof, by rapid drying. The milk fat content shall not be less than 20% of the finished product. In our country, khoa of three varieties, viz. *Pindi, Dhap* and *Danedar* is produced. *Pindi* type of khoa has lowest moisture content. Product obtained from buffalo milk is considered superior being whiter in colour and having soft smooth body and granular texture.

Chhana: It is a popular indigenous milk product obtained by acid coagulation of hot milk followed by draining of whey. According to PFA, the product shall contain not more than 70% moisture and not less than 50% fat on dry matter basis. *Chhana* is used as a base and filler for preparation of a large number of sweets such as *rasogolla, sandesh, ras-malai*, etc. Cow milk *chhana* with moist surface, light yellow colour, soft body, smooth texture and mild acidic flavour is more suitable for Bengali sweets preparation than buffalo milk *chhana*.

Ghee: Ghee is the most important traditional Indian milk product being extensively used for dietary and religious purposes. Cow ghee is golden yellow in colour whereas buffalo ghee is greenish in colour. Ghee is characterized by its pleasant, cooked and rich flavour. The preferred texture is of large uniform size grains uniformly distributed throughout the lot. Ghee produced at different places and different conditions vary in quality. It is refined by heating in large pans at 70-80°C, the product being allowed to settle for 2 to 5 hours after removing the scum formed at the top.

Dairy By-Products: A byproduct may be defined as a product of commercial value produced during the manufacture of a main product. Skim milk, whey and butter milk are the industry's principal byproducts, residues from the manufacture of cream, cheese and butter, respectively.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give the average composition of cow milk.

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2. Enumerate the important steps involved in clean milk production.

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3. Define pasteurization.

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6.4 POULTRY

Poultry keeping in our country is as old as our civilization. Red jungle fowl found in India and its neighbouring countries is considered to be progenitor of all domestic breeds of fowl. Now, we include ducks, geese, turkeys, pheasants, pigeons, peafowl, guinea fowl and chickens in the list of species under the general term poultry. Chicken, the most popular domesticated poultry, account for more then 90% of the total poultry population of the country. The poultry provides us eggs and chicken.. Rural backyard poultry contributes about 30% of the egg production. The Govt. of India has taken a new initiative of development of rural backyard poultry with a more holistic and self-reliant approach. Let us know more about eggs and poultry.

6.4.1 Poultry Production

The current poultry population in the country is above 435 million and accounts for 4% of the world poultry. The common breeds are shown in table 6.7.

Table 6.7: Common poultry breeds

S. No.	Breed	
1.	American Breeds	Plymouth Rock, Rhode Island Red, New Hampshire
2.	Asiatic Breeds	Brahma Cochin Langshan
3.	Mediterranean Breeds	Leghorn Minorca
4.	English Breeds	Cornish Australorp
5.	Indigenous Breed	Aseel Busra Chittagong, Kadaknath

The important economic traits in reference to rearing of poultry at small scale for egg purpose are - egg production, egg weight, egg quality, body size and confirmation, growth, feed efficiency and fertility and hatchability. Production economics of a commercial layer (for egg purpose) is entirely different than that of a commercial broiler (chicken purpose). The main attributes of a commercial layer are high egg production, low body size, less feed consumption, optimum egg size, good egg quality and high mobility and of a commercial broiler are high juvenile body weight especially at the marketing age, better feed efficiency and low brooder house mortality.

Hatching of Eggs: Hatching is production of baby chicks from fertile eggs. In early days eggs were hatched by placing them under broody hens and desi hens were ideal for this purpose. At present, incubators are used to hatch eggs. They provide similar environment as that of broody hens but more efficiently. Incubators can hatch several thousands egg at a time. The physical factors necessary for successful incubation are temperature, humidity, gaseous environment and turning of eggs. The incubation temperature usually varies from 37.2 – 37.8º C (99.5º F to 100.5º F). In fowls, the hatching period is 21 days. For obtaining better hatch and healthy chicks, the incubators and hatchers should be neat, clean and free from microbial load and should function properly.

6.4.2 Poultry Management

It refers to the husbandry practices to maximize the efficiency of production by satisfying the basic needs of the birds. It involves the management of chicks, layers and broilers.

a) *Chick Management:* It is also known as brooding management. The chicks are transferred to a brooder house immediately after hatching and reared there for 6 to 8 weeks of age. Brooder house should be draft-free, rain-proof and protected against predators. Suitable litter material like saw dust and paddy husk should be spread to a depth of 5 cm. depending upon their availability and cost. Right temperature in a brooder house is very essential. Too high or too low a temperature slows down growth and causes mortality. During the first week the temperature should be 95º F (35º C) which may be reduced by 5º F per week during each successive week till 70º F (21º C). The behaviour of chicks provides good indication of whether they are getting desired amount of heat. Infrared lamps are also good for brooding. Plenty of clean and fresh water should be provided.

b) *Grower Management:* The objective of the growing phase is to produce a pullet (young hen) which will come to lay around 20 weeks of age with an average body weight of 1.2 to 1.4 kg. Grower management especially remains the same as that of chick management except for the additional floor, water and feeder space. The floor, water and feeder space required for a grower are 950-2350 cm^2, 1.5 to 2.5 cm. and 7.5-12.5 linear centimeter, respectively. Water is essential and its requirement depends upon temperature, humidity, age, dietary constituents, activity and air movement. Deworming is essential and is done bi-monthly to keep the birds free from parasitic diseases. De beaking is recommended between 12 and 16 weeks. Feed restriction is essential to reduce the feed cost and productivity.

c) *Layer Management:* The flock should be transferred from grower to layer house at 18 to 20 weeks of age. Floor space of 2300-2800 cm^2, feeder space of 10 cm. and water space of 2.5 cm. per bird are recommended for egg type chicken in floor house. One laying nest for every 4 pullets is necessary. A platform in front of the nest entrances helps the birds to have access to the nest. From 21 weeks, the lighting should be increased gradually till it reaches 16-17 hours per day and maintained at that level thereafter. Correct lighting boosts up egg production by 5 to 10 percent.

d) *Male Management:* Breeder mate management remains essentially the same as that of layer management except that male breeder's diet should be fortified with extra calcium, manganese and vitamin E to ensure proper fertility.

e) *Housing:* The objective of providing housing to poultry is to protect from sun, rain and predators. Poultry houses should be well ventilated, reasonably cool during summer and warm in winter. In our country, open-sided poultry houses are popular. The poultry house should not be expensive. The floor should be moisture proof, free from cracks, easily cleaned, rat-proof and durable.

f) *Feeding of Poultry:* Feeding constitutes an important concern in poultry management since major expenditure (60-70%) in poultry raising is feed cost. More than 40 nutrients are required. The birds should be given balanced ration, i.e. supply different nutrients – i.e. fat, carbohydrates, proteins, minerals, vitamins and water in right proportion. Conventional poultry ration include many cereals like maize, rice, wheat, barley and a few by-products such as wheat barn or rice polish, animal and vegetable protein sources like fish-meal, meat-meal, soyabean-oil-meal, groundnut cake, etc. The ration is fortified with adequate quantity of minerals and vitamins either in chemically pure form or through ingredients known to be rich in these nutrients. Efforts are being made to use agro-industrial products to replace more costly ingredients.

6.4.3 Composition and Nutritive Value of Egg

The main parts of an egg are shell (8-11%), albumen (56.61%) and yolk (27-32%). Egg contains about 2 parts white to 1 part yolk by weight. The whole mixed egg contains about 65% water, 12% protein and 11% fat. The composition of the white and the yolk differ considerably. The yolk is rich in fat, fat soluble vitamins A,D,E, and K and in phospholipids including the emulsifier lecithin (Table 6.8)

Table 6.8: Chemical composition of the hen's egg

Fraction	**%**	**% of Constituents**			
		Water	**Protein**	**Fat**	**Ash**
Whole Egg	100	65.5	11.8	11.0	11.7
White	58	88.0	11.0	0.2	0.8
Yolk	31	48.0	17.5	32.5	2.0
Fraction	**%**	**Calcium carbonate**	**Magnesium carbonate**	**Calcium phosphate**	**Organic matter**
Shell	11	94.0	1.0	1.0	4.0

Nutritionally, eggs are a good source of fat, protein, vitamins and minerals, especially iron. It is often used as a standard for measuring the quality of other food proteins. Its high nutrient content, low calorific value and easy digestibility make it a valuable protective food in human diet.

Quality Factors

The important quality attributes of eggs are: egg size, cleanliness and soundness of shell, albumen and yolk quality, nutritive value, wholesomeness, functional properties, etc. Egg size can be adversely affected by inadequate level of protein and essential fatty acids in layer's (hen's) diet and high environmental temperature.

The quality of egg starts deteriorating soon after it is laid unless proper care is taken to maintain it following better methods of assembly, cleaning, grading, packaging, storage, transport and distribution. Fresh eggs have a high yolk rather than a flat yolk and a larger amount of thick white relative to running thin white. This causes a stale egg to spread out over a larger area than a fresh egg. Fresh eggs taste better, are nutritious superior, are easier to separate into whites and yolks for manufacturing purposes, and perform better in whipping and baking applications. Storage is best at a temperature slightly above the freezing point of the egg. For short period of storage, fresh eggs could be stored at 12.5º C to 15.5º C (55-60º F) and 70-80% RH. For long term storage, the room temperature should be at – 10º C (14 $\pm$ 1º F) and RH 80-90% as this relative humidity will sufficiently retard evaporation without danger of mould growth.

6.4.4 Preservation of Shell Eggs

Preservation of shell eggs are based on simple principle of retarding the microbial growth and sealing pores of the shell to minimize the evaporation of moisture and escape of gases. The common methods include i) thermal processing, ii) immersion in liquid, iii) oil-coating, iv) cold storage, and v) pickling.

In flash heat treatment, the eggs are immersed for 2 to 3 seconds in water at 71º C. The treatment destroys bacteria present on the surface of shell and seals the shell internally by coagulating a thin film of albumen immediately below the shell membrane. Oil treatment preserves the egg by forming a thin film on the surface of shell and thereby sealing the pores. This treatment should be given preferably within a few hours of lay to retain better internal quality. The eggs should be washed before coating. The oil used must be colourless, odourless, less viscous and free from fluorescent materials. Eggs can be dipped in oil or sprayed with it. Vegetable oils such as groundnut oil mixed with 0.0125% BHT is a good sealing agent, but the mineral oils of food grade are preferable as they are less susceptible to oxidative changes during storage. Under village conditions, immersion in lime water and water glass is also useful. In lime sealing, the eggs are immersed in clear lime solution (prepared by using quick lime, water, table salt) and then taken out. Eggs are dried at room temperature and transferred to filter flats.

Dehydration and freezing are the commonly used methods for the preservation of liquid whole egg, albumen and yolk separately, depending upon their use in bakery products, confectionaries and other food or non-food products.

6.4.5 Processing of Poultry Meat

Poultry meat has high nutritive value. It is easily digestible and its protein content is in general higher and fat content lesser than in most of the red meats. Chicken meat contains all the essential amino acids and quantitatively compares closely with milk and egg proteins. It has less carbohydrate, but is a good source of Vitamin B, iron and phosphorus.

The scientific and hygienic processing of poultry is must for processing the quality of meat. Figure 6.3 gives the flow sheet for preparation of ready-to-cook chicken. These are packed immediately either in polyethylene bags of medium density (200 gauges) or vacuum packaged in heat shrinkable film bags.

Procurement of Birds

Handling period (withdraw feed only)

Ante-mortem inspection

Killing-bleeding

Scalding (58º - 60° C for 1 to 2 minutes)

Defeathering

Singering

Hand finish

Evisceration

Post-mortem inspection

Washing and cleaning

Chilling (in slush ice to 4° C or lower)

Draining

Packaging

Chill storage at 2° C (to be sold within a week or 10 days)	Frozen storage at - 18° C after freezing at - 40° C (for storage up to 9 months)

Figure 6.3: Flow sheet for the preparation of ready-to-cook chicken

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is brooding?

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2. Give the composition of white egg and yolk.

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3. Enumerate the methods for preservation of shell egg.

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6.5 MEAT

We know that the word “meat” in its broadest sense means the flesh of animals, especially of mammals or birds rather than fish. However, the term in reference to food processing includes all those parts of the animals that are used as a food by man, and covers glands and organs such as tongue, liver, heart, kidney, brain and so on besides the skeletal tissue or flesh. In our country, sheep, goat, pig and poultry are reared primarily for meat production. Though meat has a very high biological value, its production and processing has always been the subject of social considerations. The per capita animal protein availability is about 10g as against the World average for 25g. Considering the targeted minimum requirement of 20g per capita per day for animal protein, 4g will come from meat remaining 16g from other livestock products. The estimated demand of meat for the present population would be 7.7 million tonnes as against the present production of 5.7 million tonnes. The meat is not an essential item of diet for a large population of the country. The annual meat production of the country is about 4-6 million tonnes and we are placed at number eight position in the world. .

We export both frozen and fresh chilled meat to more than 54 countries in the world. There is, however, very little processing of meat (1%) for ready to eat meat products. About 40 million people are engaged in meat sector, namely, trade of live animals, hides, bones, caesings, horns and hooves, etc. This sector when organized on scientific lines will generate more employment in rearing of animals on scientific lines and processing of slaughter house byproducts for allied industries. The country is poised to achieve the Pink Revolution through buffalo rearing for meat production. A brief profile of meat production and meat products in reference to food technology is given below.

6.5.1 Structure and Composition of Meat

Meat is predominantly composed of muscle tissue along with various types of connective tissue. A cut of meat consists of lean tissue, which, aside from water, is chiefly protein, with some fatty tissue and bone. Muscle is composed of bundles of hair like muscle fibers. These protein muscle fibers are held together by proteniaecous connective tissue which merges to form a tendon which in turn connects the muscle to bone. The connective tissue contains two proteins called collagen and elastin. Collagen on heating in the presence of moisture dissolves and yields gelatin. Elastin is tougher and is a constituent of the ligaments. In well fed animals, fat penetrates between the muscle fiber bundles and this is fat marbling. There are relationships between muscle structure and meat technology. Thinner muscles fibers are tenderer than thicker muscle fibers, and thinner muscle fibers are more common in young animals. Marbled fat within the muscles makes for more tenderness.

Composition of Muscle Tissue: Muscle tissue contains approximately 75% water and 25% solids, of which 19% are proteins. Lipids constitute about 2.5% to 5% of muscle. It contains Cu, Zn, Na, Hg, K, Mg and low amount of Ca. Most of the calcium in the body of an animal is found in the bones, so the edible portion of meat is low in this mineral. Liver is an especially rich source of iron and a concentrated source of Vitamin A. Meats are excellent source of niacin and riboflavin and are good source of thiamine.

6.5.2 Nutritive Value

Meat is a very nutritious food. It is almost fully digestible. The nutritive value of meat is attributed to its abundant high quality proteins, essential fatty acids, some important minerals and B complex group of vitamins (thiamine, riboflavin, niacin, pantothenic acid, B_6, folic acid, biotin and B_{12}). Calories supplied by meat vary with the contents of fat. Organs such as tongue, brain, thymus (sweet breads), heart, liver and kidney are called variety meats. They are also excellent source of nutrients. Variety meat (organ meat) especially liver and kidney contain appreciable amounts of vitamins A, B, C, D, E and K.

6.5.3 Production of Wholesome Meat

The essential stage requiring applications of effective measures for production of quality meat are:

i) Animals should be given sufficient rest before slaughter.

ii) Ample drinking water should be available to them and about 1 hour before slaughter, they should be given very little to eat but should not be starved.

iii) The weak and diseased animals should not be slaughtered. Only those animals which produce carcasses of quality and nourishment should be slaughtered.

iv) Slaughtering and bleeding of the animals should be done without causing excitement.

v) The carcass unfit for human consumption should be destroyed.

vi) Ensure environmental sanitation during transportation of meat and it is safe to the public.

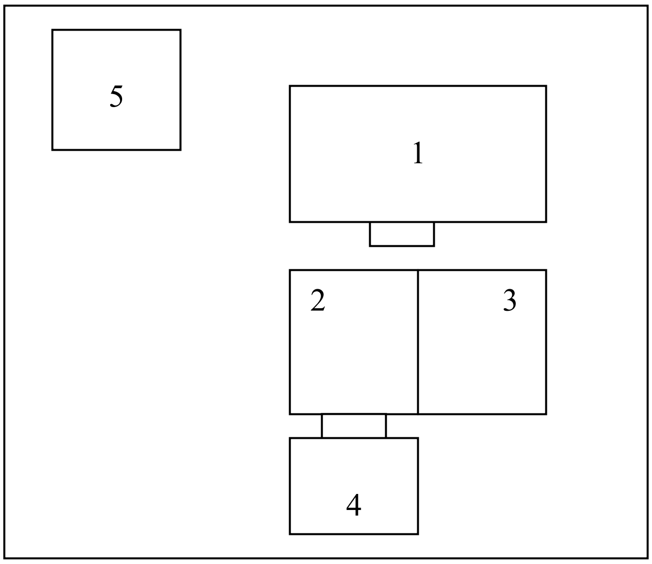
vii) Ensure personal hygiene of all those engaged in slaughtering, dressing and handling of meat.

viii) Process equipment should be kept thoroughly clean and disinfected before use.

ix) Meat and meat products should be stored in fly-proof containers. These must be refrigerated during summer.

Slaughter Houses or Abattoir: Slaughter houses or abattoir means any premises that is approved and registered by the controlling authority in which animals are slaughtered and dressed for human consumption. Abattoir may be small, medium or large based on the number of animals slaughtered. Based on the level of technology adopted the operations are manual, semi-mechanized or fully automatic. The slaughter houses play an important role in the processing of animals for production of safe and wholesome meat and in the effective recovery of by-products.

The important sections of the modern abattoir are (a) Lairage for resting the animals prior to slaughter; (b) slaughter hall; (c) By-product room; (d) Meat cutting room (optional); and (e) Rendering room (optional) or simple system of treating offals or condemned carcass. The building should be furnished with fly- proof system, sufficient lighting, ventilation and water supply (Fig.4). Let us appreciate that application of modern scientific methods for processing of meat in abattoirs would provide safety, value addition, convenience and consumer satisfaction. The Govt. of India has initiated a number of programmes for improvement and modernization of slaughter production.



1. Lairage
2. Slaughter room
3. By-product room
4. Holding room
5. Effluent room

Figure 6.4: Slaughter house

Towards this end, we as trained technicians, should ensure for humane methods of slaughter and production of meat under hygienic conditions. Slaughtering of animals in unconscious state will facilitate prevention of cruelty. The essential processing steps in abattoir are: i) resting animals in lairage prior to slaughter; ii) ante-mortem inspection; iii) stunning (depends on religious customs); iv) slaughter and bleeding on the cradles; v) skinning, dressing and evisceration on the overhead rail; vi) post – mortem inspection; vii) washing; and viii) holding the carcass in chill room (optional); ix) cutting and packing (optional).

6.5.4 Preservation Techniques

Meat is a highly perishable commodity due to nearly neutral pH (low acid food), high moisture contents and rich nutrients. Various methods to extend the shelf-life of meat are: i) chilling / refrigeration; ii) freezing; iii) curing; iv) smoking; v) thermal / processing; vi) canning; vii) dehydration; and viii) irradiation.

Refrigeration/chilling: This is the most widely used method of preservations for short terms storage of meat. Storage of fresh meat is done at a refrigeration temperature of 2 to 5^0 C. Fresh meat can be maintained in good conditions for a period of 5-7 days at a refrigerated temperature of 4 ± 1^0 C. The cooling slows down the microbial growth and enzymatic as well as chemical reactions. Processed meat products are also stored under refrigeration till these are fully consumed.

Freezing: It is for the long terms preservation of meat. It stops the microbial growths and retards the action of enzymes. Large quantities of meat and meat products are stored, distributed and marketed in frozen form. A product can be considered frozen when its centre has a temperature of -12^0 C or less. The speed of freezing is a very important factor as frozen meat quality depends mainly on the size of the ice crystals formed. The quality of meat and meat products can be preserved for months together during frozen storage at -10^0 C. However, a storage temperature of -18^0 C is recommended because at this level almost all water in meat is frozen and minor fluctuations can be taken care of.

Curing: Preservation of meat by heavy salting is an age old practice. Sodium chloride and sodium nitrite are commonly used. Now a days curing of meat products is mainly for specific flavour and colour development and preservative effects of curing ingredients is an added advantage.

Smoking: Smoking helps in preservation of meat. It contains a large number of wood degradation products such as aldehydes, ketones, organic acids, phenols, etc. which exert bacteriostatic effect besides imparting characteristic smoky flavour.

Thermal processing: Thermal processing as a preservative method is employed to kill the spoilage microorganisms as against the refrigeration methods that slows or stop microbial growth. Pasteurization and sterilization are common heat processing operations that are generally used.

Pasteurization refers to moderate heating in the temperature range of 58^0 C to 75^0 C. The process extends the shelf life but the product needs to be stored under refrigeration. Sterilization refers to severe heating above 100^0 C whereby all spoilage microorganisms in meat are killed. It renders the product commercial sterile. Such meat products have a recommended shelf life of two years in cans and one year in retort pouches at ambient temperature in tropics.

Canning: It is a process of preservation achieved by thermal sterilization of a product held in hermetically sealed containers. The product have a shelf life of at least 2 years at ambient temperature. The steps involved are (i) Preparation of meat and gravy, (ii) Precooking of meat, (iii) Filling in cans, (iv) Exhausting, (v) Seaming, (vi) Retort or thermal processing, (vii) Cooling and (viii) Storage.

Dehydration: Removal of water from meat lowers the water activity considerably to prevent the growth of spoilage organisms. Freeze drying of meat is a satisfactory process of dehydration preservations due to better reconstitutions properties, nutritive quality and acceptability. Freeze dried products are packaged under vacuum and have very good storage stability. The process has been largely used for preparations of the dehydrated meat soup mixes.

Irradiation: Food irradiation is referred as cold sterilization as microbial destruction of foods take place without significantly raising the temperature of food. A doze of 50-100 k rad (radurisation) can enhance the shelf – life of fresh meat cuts and poultry products by 19 days whereas a doze of 4-5 M rad (radurisation) can sterilize pork, poultry and fish.

6.5.5 Meat Products

Meat cutting: Meat cutting refers to the skill of separation of carcass into wholesale primal cuts in order to facilitate requirements of meat trade, cater to the consumer preference and convenient handling by the butchers. The basic requirements in cutting are:

i) The carcass has to be essentially chilled for proper meat cutting and trimming job.

ii) Meat cutting room should be maintained at a temperature of 15-20^0 C and relative humidity of 80%. This environment is wholesome for meat and convenient to workers.

iii) All the meat cutting equipment and machinery should be made up of stainless steal and be sufficiently sharp.

iv) Cutting methods varies from country to country. Bureau of Indian Standards (BIS), specify the division of carcass into right and left sides. In our country, people go for six cuts only – neck, shoulder, rack, foreshank and breast, loin and leg.

Tenderizing meat is another important operation which is done by using mechanical methods, enzymes and salt. It affects palatability of meat.

Type of products: Meat products include a variety of products such as sausages, cured and smoked meat products (ham, bacon), canned meat (canned beef, luncheon meat, canned hams) and cooked meat products (patties, kababs, meat balls, nuggets). The purpose of meat processing to products are primarily preservations by inhibiting or preventing spoilage, improving the palatability and providing variety for trade. Meat processing to products facilitates utilization of certain cuts from the carcass which are having poor utility otherwise. The processing also help in development of convenience products for consumers. Economics of meat processing rests with the ability to utilize fats and other carcass trimmings and low value carcass cuts and by products to produce acceptable products.

Nature and role of ingredients: Meat quality plays an important role. Additives such as water or ice, salt, phosphate, nitrate, nitrite, sugar and anti-oxidants are added to improve product quality characteristics during processing. Ice chills meat during chopping or mixing operations and prevents mechanical over-heating, helps in dissolving salts, gives fluidity and facilitates proper filling. Salt reduces microbial growth, solubilizes muscle protein and imparts taste. Phosphates increase water holding capacity, fat binding, emulsion stability and ensure decreased cooking losses. They have a synergistic effect in improving the quality of meat products in combination with 1 to 2 % salt, and are used at 0.5 % level. Sugar at the level of 0.5% is added to provide flavour, mask the salt flavour and act as a preservative. Spices and condiments such as onion, ginger, black pepper, cloves, etc. are also used to improve flavour and taste of the meat products.

Processing methods: Processing refers to any treatment including salting which brings about a substantial chemical and physical changes in the natural state of meat. The preservatives processes such as curing, smoking, cooking, canning, freezing, dehydration, are also used in meat product preparations. Processing imparts considerably shelf stability to meat. The common processing techniques in reference to meat product preparations include: (i) comminution, (ii) emulsification, (iii) meat extension, (iv) pre-blending, (v) hot processing and (vi) cooking.

Meat products: Meat products are classified into the following groups

i) Cured and smoked meats
ii) Sausages
iii) Intermediate moisture and shelf stable meat products
iv) Restructured meat products
v) Canned meats
vi) Other meat products

Ethnic meat products: The range of popular products include, meat curries with gravy, fry or *pulav* (with rice) kababs (*sheek kababs, shami kababs, boti kababs), tandoor products* (tandoor chicken), grilled products and pickles.

By-products: Animal by-products are available from live animals, slaughtered animals and dead animals. The returns from the by-products are also important as meat forms only one–third of live weight of the animal while by-products from two–third. Utilization is important not only to ensure cost-effective utilization process but also for proper disposal to prevent environmental pollution and adverse effect on the main enterprise. Edible by-products from slaughtered animals include blood, variety meat, organ meats (tongue, heart and liver), casing and bones. Non–edible by-products include blood (blood meal), bones (bone-meal, ossein), horns and hooves, gastro-intestinal contents (feed, fertilizers), glands (hormones) and bile (bile salts). Dead animals are also a significant source of useful by-products when collected and processed. Hides and skins, horns and hooves, bones and bone – products, meat-meal and technical fat are the useful products from dead animals.

Among the animal by-products leather and leather products, bone and bone products, and woollen carpets are the major items of export. Other by-products those are exported include animal casings, edible offals, bile paste, gallstones and bristles. Animal glands and organs, viz. ovary, testis, pituitary, adrenal, pineal, parathyroid, thyroid, thymus, spleen, bile, lungs, liver, stomach, brain, spinal column, and seminal vesicles are utilized for medicinal and pharmaceutical purposes.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State the measures for production of quality meat.

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2. List out various methods used to extend the shelf life of meat.

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3. Name some of the value added products prepared from meat.

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6.6 FISHERIES

Fish is a valuable food due to presence of high quality proteins, i.e. presence of essential amino acids and fat (high proportion of poly unsaturated fatty acids - PUFA); rich source of B group of vitamins namely thiamine, riboflavin, niacin and pantothenic acid and important minerals such as iodine, phosphorus, active iron and sodium. The composition of flesh of fishes is (a) water 80%, (b) protein 15-25%, (c) mineral matter 1-2% and (d) other constituents 1%. The consumption of fish and fish products is continuously increasing. The nature has bestowed on India a wide variety of fishes. The aquatic endowment is supporting more than 2200 fishes, out of which nearly 1440 species are marine species, 143 species are brackish species, 544 warm water species and 37 are cold water forms. Let us know more about fish production, preservation and processing.

6.6.1 Growth rate

The country has witnessed a quantum jump in the fish production. The country occupies third position in the world and second position in the inland fish production. The fish production is the fastest growing sector in the agriculture. As compared to agriculture and animal husbandry, the fish production rate per unit area is much higher in terms of productivity as well as income. The growth rate of 2.5 percent and 8.0 percent has been proposed for marine and inland fisheries, respectively during the tenth plan. By the end of tenth plan, this will enable a total fish production of about 8.2 million tonnes with 3.3 million tonnes coming from marine sector and rest from inland sector.

Fish is a highly perishable food and therefore due importance be given for marketing, processing, preservation and keeping quality of fresh fish. Lowering, the temperature of fish from 10° C to 0° C, delays the growth phase of micro-organisms that are present and cuts the spoilage by a factor of 5 to 16. Therefore, the fresh fish should be refrigerated (near 0° C) immediately.

6.6.2 Culture Fisheries

The fish culture in ponds and paddy is an age old practice. A series of activities such as controlled breeding in captivity, production of quality seeds in sufficient quantities, rearing of spawn to fry stage, fry to fingerling stage and ultimately raising the table size are christened under the scientific fish farming. The induced breeding in captivity is widely used to get adequate quantity of quality seeds of major cultivated fishes. The process of releasing egg by female and milt by male is called spawning. The mature fishes are induced to breed by giving the pituitary injection. The hormone pellets are implanted into muscle during initial period of gender development for inducing maturation and spawning. Fishes having developed gonads are called brood stock. Hatchery management is an essential component under scientific fish farming. It involves supply of quality water, brood stock development, spawning operation, incubation of eggs, rearing of larvae from egg to post larval stage, nutrition and artificial feeding and health monitoring. The quality of water is very vital component for the survival and growth of larvae and post larvae. It is also important to maintain favourable temperature, water level, flow of water and adequate level of oxygen during larval rearing.

Construction of Fish Farm

The ponds are constructed to have high survival rate. The ponds are classified into nursery pond, rearing pond and stocking pond. The nursery ponds are used to nurse the spawn upto fry stage and are small and shallow. The rearing ponds are used to rear fry up to fingersling stage. The stocking ponds are used to grow the fish to marketable size. Generally, rectangular shape ponds are constructed with a depth of 0.5 to 0.10 m for nursery ponds, 0.6 to 1.5 m for rearing ponds and 1.0 to 2.5 m for stocking and brooder pond. An assured supply of good quality water free from pollution and turbidity is to be ensured. The pH of water should in range of 6.5 – 7.5 and for correcting the pH liming is done. The optimum concentration of dissolved oxygen (above 5 ppm) is maintained by adequate aeration by means of aerator, paddle wheel aerators, surface agitators and air blowers. The practice of using composite fish culture has revolutionized the aqua food sector in the country. The feed management and health management also play an important role in productivity.

Aquaculture has mainly contributed to the high growth of inland fisheries (6.6% per annum) as compared to marine fisheries (2.2% per annum) during the nineties. Indian major carps/ Labeo rohita (rohu), Catla catla (catla) and Cirrhinus mrigola (mrigalo) contribute about 78% of the total aquaculture production. The productivity has also gone up from about 600 kg/ha year in seventies to about 2000 kg/ha year.

6.6.3 Marine Capture Fisheries

We know that the country has a long coastline of 8118 km and an equally large area under estuaries, backwaters, and lagoons good for developing capture as well as culture fisheries. After declaration of the Exclusive Economic Zone (EEZ) in 1997, the area available to India is about 2.02 millions sq. cm. The harvestable potential of marine resources in EFZ has been estimated at about 3.921 million tonnes. The marine fishing fleet comprises about 0.281 million traditional craft (including about 44578 motorized traditional craft), 53684 mechanized chained craft and about 170 large fishing vessels of 21 m overall length (OAL) and more. The major fishing activities are concentrated in the areas within 0 to 70-80 m depth zone. Fish production has increased over the years with the motorization of traditional craft and introduction of mechanized boats in the traditional sector as well as diversification of fishing effort beyond 50 m depth.

As spoilage of fish starts from the time it is caught, the proper storage, preservation and prompt disposal or transport services are essential. The wastage is acute during monsoon when upto 30% of the catch is lost. Therefore, strengthening of post-harvest infrastructure such as storage facilities, ice plants, cold chains, roads and transportation etc., as well as effective marketing system in identified areas are the key requirements for the development of this sector.

6.6.4 Post Harvest Care

As we know fish is a highly perishable and decomposes quickly. The problem is acute in our country as heat and moisture promotes deterioration. Bacteria of water and air attack the flesh slowly at first and more rapidly later. Chemical changes cause breakdown of protein and other nitrogenous matter leading to the production of substances like hydrogen sulphate and indol. The characteristics odour of stale or spoiled fish is due to trimethyl amine which is formed by reduction of tri-methyl oxide. Fishes are preserved by various methods such as drying, salting, pickling, smoking, canning, chilling and freezing. Before preservation, fishes are washed with clean water to remove saline, blood stains, mud and sand. Larger fishes are gutted (i.e. on the internal organs or vice-versa are removed) and the body county is washed.

To remove natural moisture from the fish tissues, fishes are cured by means of heat, sun dry air and salt all along the coast. Drying of small marine fishes such as ribbon fish, silver bellies and Bombay duck in sun or shade is a very ancient method of fish preservation. In this method fishes are spread on the open sandy beach, mats, bamboo platform or hung on ropes/rods. Mechanical drier are also used for this purpose and this method yields high quality products which retains the nutritive value and flavour. Salting is a form of pickling in which common salt is used to prevent bacterial growth and methods of dry salting and wet salting are employed. In the dry salting method, fishes are rubbed with salt powder and than packed in the plastic/cemented tanks. In between two layers dry salt is applied and after stipulated period these fishes are removed, washed in the salt water and then dried. In wet salting method, gutted and cleaned fishes are placed in the container containing concentrated salt solution and stirred properly. Wet salted fishes are sold in the market without drying. In smoking, wood smoke is utilized as a preservative. In this method, cleaned and gutted fishes are soaked in the salt or brine for a short period and then suspended on rod in the smoke house. In chilling, fishes are packed in ice and then saw dust or rice husk is sprinkled over it to prevent the melting of the ice. Freezing is the most modern method of preservation. Fish intended for long storage are frozen in large deep freezers. Individual quick freezing method is gaining popularity. Frozen fishes retain their nutritive values for a longer time.

Value added products: A number of value added products are available in the market, viz. battered and breaded products like fish fillets, fish cutlets, fish cakes, fish burgers, fish balls, fish sausages, fish noodles, fish rolls, fish patties, stuffed squids, etc. The switch over from block freezing to individually quick frozen (IQF) products has changed the profile of value added products.

IQF provides, lobster, imitation products like kamabaka, crab legs, imitation shump are becoming popular. The value added products like (i) prawn and fish pickle, (ii) fish and prawn papad, (iii) fish jhuri bhagra, (iv) fish noodles and (v) fish pulp can be prepared dry woven fishers also. The techno-economic advantages of the products are (i) wide acceptability (ii) greater shelf life, (iii) more palatability, and (v) stringent quality control. There is a good potential for export of preferred products.

By-products and other uses: Fishes are also source of numerous byproducts such as (i) Fish oil, (ii) Fish-meal, (iii) Fish flour, (iv) Fish proteins, (v) Fish glue and singlass. Two important fish oils are (i) Liver oil and (ii) body oil. Liver oil is popularly known as cod-liver oil. There are numerous by-products besides oil, which are economically useful. The most important are fish-meal, fish-flour, fish-protein, fish-ghee and fish-skin.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is spawning?

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2. Enumerate the methods used for preservation of fish. Name a few value added products.

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3. Give the nutritional importance of fish.

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6.7 LET US SUM UP

The country has a considerable livestock population. Processing and production of value added products hold an important place in the national economy. We are the largest milk producers in the world. The quality of milk plays an important role in processing of milk and milk products. The important value added products from milk are butter, concentrated and dried milk products, ghee, cheese, frozen dairy products, *khoa, chhana* and a range of by products such as skim milk, whey, etc. The poultry provides us eggs and chicken. The major expenditure in poultry raising is feed cost. The methods used for preservation of shell eggs are based on retarding of microbial growth and sealing pores to minimize the evaporation of moisture and escape of gases. The meat production in our country is largely a byproduct system of livestock production utilizing spent animals at the end of their production life. Meat is a highly perishable commodity and methods to extend the shelf life are (i) chilling/refrigeration; (ii) freezing (iii) curing (iv) smoking (v) thermal processing (vi) canning (vii) dehydration and (viii) irradiation. The common indigenous popular products are meat curries with gravy, fry or *pulav* (with rice), *kababs* (*sheek kababs*, *shami kababs, boti kababs*), *tandoor* products (*tandoo*r chicken), grilled products and pickles. Fish is a source of cheap animal protein. It is highly perishable and various methods adopted for preservation are drying, salting, smoking, canning, chilling and freezing. Cod-liver oil one of the important by-products.

6.8 KEY WORDS

Preservation : Aims to inhibit microbial spoilage and arrest physio-chemical changes which bring about deterioration in quality.

Lactose : A type of natural disaccharide consisting of glucose glactose present in milk.

Brooding : Rearing of chicks upto 6 to 8 weeks of age.

Milk : It is the lacteal secretion of the mammary lands of animals.

Milk separation : The separation of milk into cream and skim milk.

Pasteurization : A process of heating every particle of milk or milk product to specified temperature and holding at that temperature for specified period followed by immediate cooling and storage at low temperature.

Hatching : Production of baby chicks from fertile egg.

Abattoir : Premises that is approved and registered by the controlling authority in which animals are slaughtered and dressed for human consumption

Comminution : It refers to subdivision or reduction of raw meat into meat pieces or particles.

Processing : Treatment or unit operations which bring about a substantial chemical and physical change in the natural state of milk/meat/fish/egg.

Post-mortem : It is the systematic exposure and scientific examination of the tissue and organ of a dead body to determine the cause of death, the nature of lesions and illness.

Aquaculture : The term relates to the culture of fish in fresh water, backlash water and sea water.

Spawning : The process of releasing eggs by female and wilt by male is called spawning.

6.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. The milk output during 2002-03 was 86.2 million tonnes and the per capita availability of milk during the period was 230 g per day.

2. Cattle population: 198.99 million and buffalo: 89.91million.

3. The livestock and fisheries sectors contributed 6.5 percent of total GDP (5.4 percent from livestock and 1.1. percent from fisheries) in 2003-03.The value of output livestock and fisheries sectors together was about Rs. 1,86,094 crores at current prices during 2002-03 (Rs.156, 080 crores for livestock sector and Rs. 30,014 crores for fisheries). Total export earnings from livestock, poultry and related products were Rs. 4734 crores in 2003-04.The sector provides large self-employment opportunities.

Check Your Progress Exercise 2

1. Milk contains on an average 87 per cent water, 3.9 per cent fat, 4.9 per cent lactose, 3.5 per cent protein and 0.7 per cent minerals, vitamin and other constituents.

2. The important steps involved in clean milk production are:

   - Clean and healthy animals.
   - The cow's body especially the udder, should be washed and brushed before milking. Diseased animals should be kept separately.
   - Clean Housing: Sheds, mangers, paddocks, water trough, floor should be clean and there should be good drainage.
   - Fly proof milking parlour.
   - Disease-free environment: milker with clean habits (nails well trimmed).
   - Clean Utensils, Milking pails.
   - Clean water.
   - Clean milking: Before milking, clean the udder with a cloth dipped in antiseptic solution such as potassium permagnate; wetting of hands with milk should be avoided.

3. The term pasteurization as applied to market milk today refers to process of heating every particle of milk to at least 63° C (145° F) for 30 minutes or 72°C (161° F) for 15 seconds (or the temp-time combination which is equally efficient) in an approved and properly operated equipment

Check Your Progress Exercise 3

1. Brooding is management of the chicks.

2. The composition is given in Table 6.9:

Table 6.9: Chemical composition of the white and yolk

Fraction	%	% of Constituents			
		Water	Protein	Fat	Ash
White	58	88.0	11.0	0.2	0.8
Yolk	31	48.0	17.5	32.5	2.0

3. The common methods of preservation of shell eggs include (i) thermal processing, (ii) immersion in liquid, (iii) oil-coating, (iv) cold storage, and (v) pickling.

Check Your Progress Exercise 4

1. The essential stage requiring applications of effective measures for production of quality meat are:

   a) Animals should be given sufficient rest before slaughter.

   b) Ample drinking water should be available to them and about 1 hour before slaughter, they should be given very little to eat but should not be starved.

   c) The weak and diseased animals should not be slaughtered. Only those animals which produce carcasses of quality and nourishment should be slaughtered.

   d) Slaughtering and bleeding of the animals should be done without causing excitement.

   e) The carcass unfit for human consumption be destroyed.

   f) Ensure environmental sanitation during transportation of meat and it is safe to the public.

   g) Ensure personal hygiene of all those engaged in slaughtering, dressing and handling of meat.

   h) Process equipment should be kept thoroughly clean and disinfected before use.

   i) Meat and meat products should be stored in fly-proof containers. These must be refrigerated during summer.

2. Various methods to extend the shelf-life of meat are: (i) chilling/ refrigeration; (ii) freezing; iii) curing; (iv) smoking; (v) thermal/processing (vi) canning; (vii) dehydration, and (viii) irradiation.

3. The value added products prepared from meat products are sausages, cured and smoked meat products (ham, bacon), canned meat (canned beef, luncheon meat, canned hams) and cooked meat products (patties, kababs, meat balls, nuggets)

Check Your Progress Exercise 5

1. The process of releasing egg by female and milt by male is called spawning.

2. Fishes are preserved by various methods such as drying, salting, pickling, smoking, canning, chilling and freezing. A few value added products are battered and breaded products like fish fillets, fish cutlets, fish cakes, fish burgers, fish balls, fish sausages, fish noodles, fish rolls, fish patties, stuffed squids, etc.

3. Fish is a valuable food due to presence of high quality proteins, i.e. presence of essential amino acids and fat (high proportion of poly unsaturated fatty acids - PUFA); rich source of B group of vitamins namely thiamine, riboflavin, niacin and pantothenic acid and important minerals such as iodine, phosphorus, active iron and sodium.

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UNIT 7 COMMERCIAL CROPS, SPICES, MEDICINAL AND AROMATIC PLANTS

Structure

7.0 OBJECTIVES

After reading this unit, you should be able to:

- state the importance of commercial crops, spices, medicinal and aromatic plants in the national economy;
- know about post harvest processing of these crops into value added products; and
- describe the by products and other uses of these crops.

7.1 INTRODUCTION

Commercial crops, spices and medicinal and aromatic plants are high value crops. These crops require special attention during production and also during post harvest processing, handling and storage. Some of these crops play a significant role in the national economy, export or in employing large number of people. Therefore, the study of these crops is to be separated from the other crops like cereals, pulses and oil seeds or horticultural crops.

The Unit 4 has been divided in three sections namely; commercial crops, spices and medicinal and aromatic plants. Under section 4.2 mainly two main commercial crops namely sugarcane and cotton are discussed. In the section

4.3, six major spices namely chilli, cardamom, pepper, tamarind, turmeric and ginger are discussed. Lastly medicinal and aromatic plants are discussed.

7.2 COMMERCIAL CROPS (SUGARCANE AND COTTON)

7.2.1 Importance

Crops, which are important from commerce points of view, are called commercial crops. Mainly two crops are considered as major commercial crops in India namely sugarcane and cotton.

Sugarcane is widely grown in almost every state of the country and two union territories. Sugar industry is the second largest processing industry in the country. There are more than 400 sugar industries in the country who receive raw material from 35 million sugarcane growers in the country. India is the largest sugarcane producer of the world and at one time (1975-76) it had exported over 1 million tonnes of sugar and earned Rs. 468.5 crores.

Wealth of Sugarcane: From energy transformation points, sugarcane is the most efficient crop. It receives the solar energy and converts it in to energy producing substances like sugar, cellulose and non-cellulose products. Thus its processing is valuable contribution to food and industry. Sugarcane produces sucrose which is a direct source of food and wide range of by products as shown in Figure 7.1. These products are useful for human and animal consumption and also provide huge renewable energy.

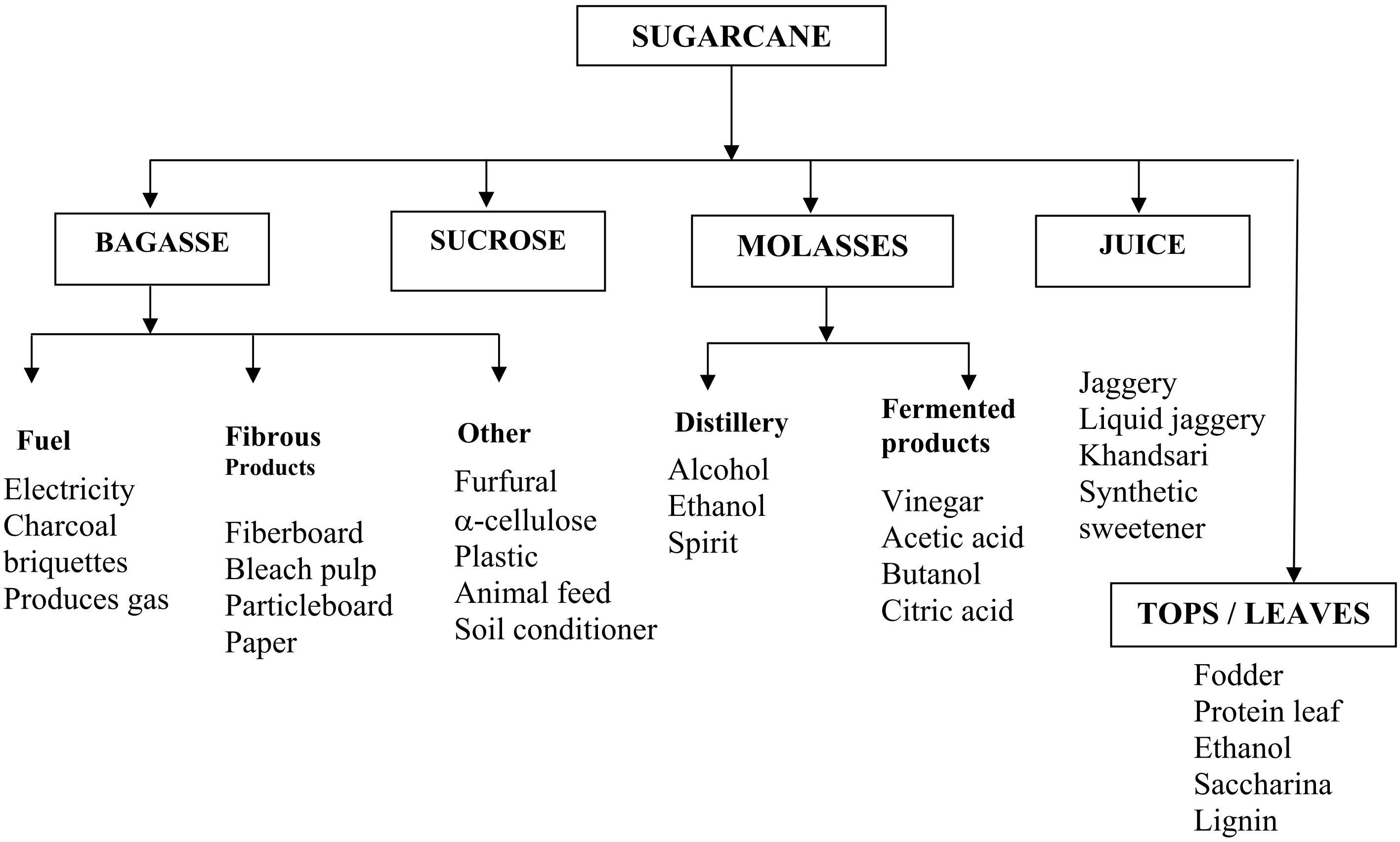

Figure 7.1: Products and by products of sugarcane

Cotton is the most important commercial crop playing a key role in economic, political and social fabric of the world. In India it is the biggest organized sector which provides employment to several million people. It is the largest industry in terms of annual value of output and labour employment. Besides this large number of power loom and handloom have employed around 2.5 million people.

Cotton is not only known for production of lint, which is the basic raw material of textile industry but also to produce cottonseed, which is rich in oil.

7.2.2 Processing of Sugarcane

In a typical sugar factory 100 tones of cane produces: Sugars (10 t), molasses (4 t), filter mud (3 t), Bagasses (30 t) and cane tops and leaves 30 t. Besides these it also can produce electricity of 1500 kW.

Juice Extraction

Sugar cane is crushed in sugarcane crusher (IS:1973-1973) in general where first dry crushing is done and about 73% of total available juice is recovered. Then wet crushing is done to recover remaining juice. IS-6983-1973 is the specification of rollers and axles for sugar cane crusher. Extracted juice is acidic (pH 5.2-5.5) in nature. It is neutralized to pH 6.4 by the addition of lime solution. In general in 100 kg juice, 1 kg lime (80-90% purity) is mixed with 4 litre of water and 60-75 ml of milk of lime is sufficient to bring desired neutralization.

Juice boiling: To avoid sugar inversion, the boiling should be done within 8-12 h of juice extraction. A traditional furnace, where *bagasse* is used as fuel should have high heat utilization efficiency and Juice clarification.

Jaggery

Jaggerry and *Khandsari* are ancient *sweetners* and still popular among masses for its high food value and medicinal properties. In India about 40% of sugarcane produced is used for making *jaggery* in the organized and unorganized sector. The *jaggery* is considered to be diuretic, refreshing tonic and cooling. Table 7.1 provides the comparison of composition of sugar, *Jaggerry* and *Khandsari.*

Table 7.1: Proximate composition of sugarcane sweeteners (100g)

Sweetener	Sucrose (g)	Reducing sugar (g)	Protein (g)	Fat (g)	Moisture (g)	Ca (mg)	P (mg)	Fe (mg)	Energy (Kcal)
Sugar	99.5	-	-	-	0.4	-	-	-	398
Jaggery solid	60-85	5-15	0.4	0.1	3-10	8	4	11.4	383
Khandsari	96	-	-	-	0.5	100	-	-	398
Bura	90-95	1-3	-	0.5	1.5	100	-	-	395
Misri	99.5	-	-	-	0.2	-	-	-	402

Source: Annual report of ISARI< Lucknow 1999-2000

The traditional process of *jaggery* preparation is shown in Figure 4.2. Sugarcane is crushed in sugarcane crusher. About 48 % of sugarcane mass as juice goes to clarifier. The clarified juice is boiled. To neutralize the juice lime is added and concentrated juice is put in the moulds (1, 5, 10 and15 kg). After cooling moulds are stored. Bagasse, which is a byproduct, is used as source of fuel in the *jaggery* preparations.

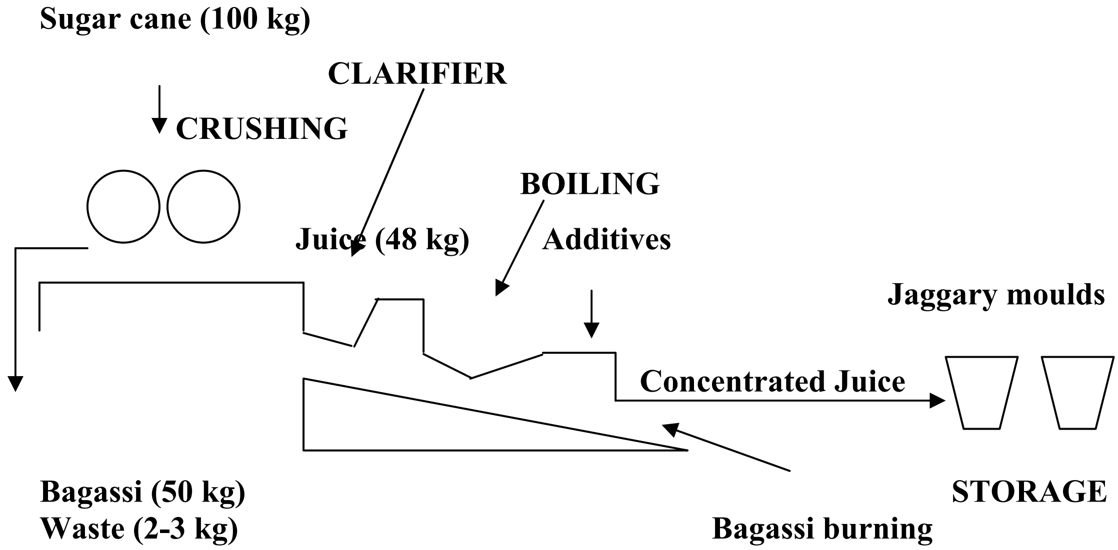

Figure 7.2: Traditional process for *jaggery* preparation

7.2.3 Byproducts of Sugarcane

Sugarcane plant has four major byproducts namely bagasse, molasses, sucrose, tops and leaves.

Bagasse

Bagasses, is the fibrous residue of cane stalk after crushing and extraction of juice. It consists water, fibers and small quantity of soluble solids. Its composition includes fiber 46-52%, moisture 43-52% sugar 3% and minor constituents 0.55%. Where as the dry bagasses composition is: Cellulose (45%), Pentosans (28%), Lignin (20%), Ash (2%) and sugar (5%).

Bagasse can also be used as –

i) **Pulp**: Bagasse can be converted in to pulp. This pulp can be used to make paper for wrapping, printing, writing, toilet, tissue, corrugated medium, linerboard etc. Fluff pulp can be used to make sanitary napkins and absorbent disposable products.

ii) **Paper Industry:** Process of paper manufacturing includes **digestion, washing, screening, bleaching, dewatering and thickening.** Bagasses are digested in close units at pre-specified pressure, temperature and time with chemicals. Later washing is done to remove the effect of chemicals.

iii) Fuel (briquettes, charcoal, produces gas)

iv) Fodder for animals

v) Production of mushroom

vi) Soil conditioner

Molasses Based Products

Molasses yield is 2.2 to 3.7% of the total cane crushed. It is graded based on total sugar content and yield of ethyl alcohol produced from it. Alcohol producing industry consume about 80-90% of the molasses produced in the country. The other important product is ethanol. The ethanol produced is used for

Ethanol

Dehydration	**Oxidation Dehydrogenation**	**Modification**
Polystyrene	Ethyl butyl acetates	Chloroform
Polyethylene	Acetic anhydride	Butadiene
Poly ethers	Charcoal	Diethyl then
	Butaaraldehyde	Ethylamines
	Acetamide	Ethyl chloride

Sucrose

Sucrose is a regenerable potential raw material obtained from sugarcane. Though it is not as sweet as saccharin, suralose, aspartame etc, but it has wide commercial applications. There are some added derivatives which have market potential such as:

- Ethers and anhydro derivatives
- Esters of fatty acids as surfactant and emulsifiers
- Sulfuric acid or sulphate esters.
- Polymers and resins, acrylics, etc

The other uses of sugarcane tops press mule and waste is in animal feed, fertilizer cane wax etc.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why sugarcane is called energy efficient crop?

2. Why cotton is the most important commercial crop?

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3. How much sugar can be produced from 1000 kg sugarcane?

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4. Why sugarcane juice is to be boiled with in 8- 12 hours of extraction?

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5. What are the medicinal properties of jaggery?

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6. List the unit operations are to be performed in paper manufacturing.

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7.2.4 Processing of Cotton

Ginning

It is an important unit operation in the handling cotton as a raw material from field to the factory for processing. It is the process of separation of lint from seed cotton. It is done either by roller gin or with saw gins.

Quality Evaluation of Cotton

The quality of cotton is judges by the quality of yarn which be spun from it. The spinning performance in expressed as **"Highest Standard Count" (HSC)** which cotton can spin. For i.e. 40 counts means one pound of a particular yarn contain 40 lakhs of 840 yards each. Based on the end-use of the yarn, certain strength standard have been prescribed. The maximum HSC for cotton is the finest count of yarn, which can be spun to satisfy the yarn strength standards. Thus important parameters are fineness, maturity and strength.

Fiber length – Longer lnited cotton provides better spinning performance than shorter linted ones.

Short staple	19 mm or below
Medium staple	20 .0 – 21.5 mm
Superior medium staple	22.0 – 24.0 mm
Long staple	24.5 – 26.0 mm
Superior long staple	27.0 mm and above

7.3 SPICES

7.3.1 Importance

The Indian spices are perhaps older than the recorded history. India is well known to the world as **Home of spices**. Spices contribute an important group of agriculture commodity as they are considered as indispensable in the culinary art for flavouring of foods. These crops will also show our heritage and national wealth in utilization of them for several medicinal uses. Some are also used as pharmaceuticals, perfumery, cosmetics etc. Besides this, spices play an important role in the national economy.

Chilli is the dried ripe fruit of genus "capsicum" which is also called as red pepper and it is considered as an important commercial crop used as a condiment, culinary supplement as a vegetable. In India, chilli is cultivated in about 10 lakh hectares with an annual production of 10 lakh tonnes, which is about one fourth of the world's chilli production. The annual Indian export of chilli in recent times is around 13000 tonnes valued about Rs. 500 million. Together with whole chilli, the value-added products like chilli powder, curry powder, chilli oleoresins etc. add a major share to our export earnings.

Among the various spices cultivated in India, cardamom is called "**Queen of spices**". It is native of India; enjoys a unique position in the International spice market. At present, India is the second largest consumer of small cardamom in the world after Saudi Arabia. The cardamom growing tracts in the country are facing severe ecological degradation due to diminishing forest cover, leaving the region open to devastation by floods and droughts. As cardamom requires tropical forest conditions for better growth, both the area and production of cardamom in the country are declining.

Pepper (*Piper nigrum*) popularly known as the **King of spices**. It is the dried fruit of perennial climbing vine, mostly found in hot and moist parts of Southern India. Kerala alone contributes 96% of the total production in India. Apart from Kerala, pepper is also cultivated in the hill districts of Karnataka and Tamil Nadu. Mostly pepper is cultivated as intercrop with other plantation crops.

Pepper is widely used as a condiment, preferred for its characteristic aroma, pungency and biting taste. It is used to garnish culinary preparations, ketchups, sauces pickles and in pharmaceutics. Indian pepper, commonly known as "Malabar pepper" is considered to the best in the world for its excellent aroma flavour and pungency. India is the largest producer, consumer and exporter of black pepper. India contributes about 35 to 40 percent to the total world production and thus occupies the unique position in the international trade of pepper. The annual production of pepper in India is in the range of 60,000-85,000 tonnes.

Tamarind (*Tamarindus indica* Linn) is one of the important economic trees of India. Tamarind is a much-loved tree throughout the semi-arid regions for its deep, cool shade and for its valuable fruit. It is an ideal plant for optimum use of wastelands. It is a regular bearer and provides assured returns to the farmers even under extreme soil and climatic conditions.

Turmeric adds typical flavour and colour in curries and makes them the best. Turmeric is also used as dye in textile industries, it is also used for medicinal purposes and cosmetics. India exports only 5-8 % of its turmeric produce and ranks 6th in spice export and earns over Rs. 100 million annually.

India is the largest producer and exporter of pepper, chilli, ginger and turmeric. It also exports substantial amount of cardamom and black pepper. India alone contributes 50% of the world ginger requirement. Ginger is used principally as an ingredient in various spices blends, food processing and beverage industry.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the indices to evaluate quality of the cotton?

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2. What should be the best quality fiber length?

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3. Name the following

   i) Home of spices : ....

   ii) Queen of spices : ....

   iii) King of spices : ....

7.3.2 Proximate Composition of Spices

Spices are an important group of agriculture commodity as they are considered indispensable in the culinary art for flavouring of foods. These crops also show our heritage and national wealth. Some are also used as pharmaceuticals, perfumes, cosmetics etc. Proximate composition of spices is given in Table 7.2.

7.3.3 Harvesting and Drying of Chilli

The crop becomes ready for harvesting in about 105-120 days after planting. The picking of ripe fruits continues for about 2 months. Chilli is picked in about 6-10 pickings with an interval of 7 or 8 days. Some traditional varieties require only 5-6 pickings; while the hybrids may require up to 12 pickings. Harvesting is done after 1 or 2 days of irrigation and picked fruits are kept in shade to avoid sunscald.

Chilli is harvested at moisture content of around 60-70% (w.b.) and need to be dried for further preservation and storage. In the absence of efficient mechanical drying systems, currently all the chilli produced in the country is sun dried.

Table 7.2: Nutritional constituents of spices per 100 g

S. No.	Nutrient	Green Chilli	Red Chilli	Cardamom	White pepper	Turmeric	Ginger
1.	Carbohydrate	3.0	31.6	45.4	68.6		66.5
2.	Proteins	2.9	15.9	10.3	10.4	8.6	8.6
3.	Fat	0.6	6.2	8.3	2.1	8.9	6.4
4.	Fiber	6.8	30.2	9.2	4.3	6.9	5.9
5.	Moisture	85.7	10.0	8.3	11.4	58	5.9
6.	Minerals	1.0	6.1			6.8	
7.	Calcium	0.03	0.16	0.3	0.45	0.2	0.1

8.	Phosphorous	0.08	0.37	0.21	0.2	0.26	0.15
9.	Sodium			0.01		0.05	0.03
10.	Potassium			1.2		2.5	1.4
11.	Iron	0.0044	0.0023	0.012	0.017	0.05	0.011
12.	Ash			5.0	1.6		5.7
13.	Vit.A (IU) Vit – C Vit – B_1 Vit – B_2 Niacin	454 111	576 50	175 12 0.18 0.23 2.3	1800	175 49.8 0.09 0.19 4.8	175 12 0.05 0.13 1.9
14.	Calorific value					390	360

Source: NIN, ICMR, Hyderabad

7.3.4 Processing and Uses of Cardamom

As the flowering continues over a long period, cardamom capsules ripen successively over an extended period. Thus, it requires several pickings. In most of the areas, the peak harvesting is continued at an interval of 15 days and completed in 8 to 10 rounds

Harvesting should be taken up only at a time when seeds inside the capsules have become black in colour. It is the index of maturity stages of the fruit. At this stage the pericarp (the seed cover or skin of the capsule) will still be green. When light picking is done, great care is to be exercised to harvest only the green and mature capsules. This process will naturally give a lower green crop per picking. When the hard picking is done, semi-mature crop is also removed. While this process could reduce curing percentage, it could increase the picking average and ensure green coloured capsules.

Bleaching is an important pre-treatment given to either dried cardamom or freshly harvested capsules as starting material. The bleached cardamom is creamy white or golden yellow in colour. The advantages of bleached cardamom are white appearance and their resistance to weevil infestation due to sulphur dioxide content. Different methods to achieve bleached cardamom and are given in Table 7.3.

Table 7.3: Treatments for bleaching of cardamom

Treatment	Concentration of content bleaching agent	Contact time (min)	Remarks
Steeping in H_2O_2 containing 0.5% sodium silicate	6% H_2O_2	15	For dry cardamom
Bleaching with H_2O_2 and SO_2 fumigation	0.3%	60	Dry cardamom
Steeping in acidified powder solution	20 g/l	75	Fresh cardamom
Subsequent steeping in H_2O_2 containing 0.5% sodium silicate	1% H_2O_2	30	Fresh cardamom

Cardamom capsules should be dried within 24 to 36 hours of harvest to avoid deterioration. Drying is one of the important unit operations as it determines the colour of the end product, which is the attractive and most important quality character. The retention of green colour is very important in cardamom drying as green coloured cardamom fetches premium price in the export market.

Cleaning of cardamom by removing the discoloured ones, split capsules and other impurities is done by manual method. The grading of dried capsules as per AGMARK specifications is generally carried out using round sieves. Mostly 7 mm round holes sieves are used for grading.

Mainly cardamom has three products namely decorticated seed or seed powder, essential oil and oleoresin. The decorticated seed or its powder has poor storability, as volatiles are lost during the storage. Thus it is stored in pods. Cardamom oil is produced by steam distillation of crushed fruits. Cardamom is used as flavouring material as whole, decorticated seed and ground powder. It has medicinal value for scanty urination, diarrhoea, dysentery, and exhaustion due to over work, depression.

7.3.5 Post Harvest Technology of Pepper and its Products

The stage of harvest is very important for the production of black pepper. Well-matured but unripe berries are harvested. Pepper becomes ready for harvest in about 6-8 months after flowering, during November-December and harvest continues up to March-April. The spikes are picked when they are blackish green and most pungent.

Harvesting is done manually, by climbing on the ladders. The well-matured spikes, of dark green colour are picked by the person standing on the ladder and dropped. The person standing on the floor will collect the spikes in the bags. A pair of women will be able to pick about 90 to 100 kg of spikes and paid @ Rs. 1 per kg of berry picked.

The harvested green spikes are some times heaped for a day, before threshing for easy separation of the berries. In few estates, mechanical threshes are used for separating and cleaning the berries. However, the threshing efficiency of these machines is only about 90 percent. The freshly harvested berries contain moisture of above 70% (w.b.). The berries as soon as they are harvested are separated from spikes and spread out on mats for drying. In about 2 days, the moisture content decreases to 20-25%. Due to enzymatic oxidation of colourless compounds present in the skin, the colour of pepper fruits turn black and masks the green colour after drying. The subsequent operations involve further drying of safe moisture level below 11% (w.b.)

Since drying with periodic turning is commonly adopted, since it is feasible when the quantity is small and monsoon does not interfere. But for large scale drying, artificial drying is preferred. The moisture in partially sun-dried pepper is brought down from 25 to 11 % in two stages in a counter current hot air flow system. After one pass in dryer, the pepper is stored for 24-48 hours, after which it is dried again to safe moisture level.

The dried pepper is cleaned for removal of extraneous matter such as dirt, girt, stones, stalks leaves, etc. Magnetic separator is used to remove metallic contamination such as iron fillings and stray nails. Vibration conveyors with inclined decks in combination of air classification are used for efficient destoning of spices. The composition of the dried black pepper is given in the Table 7.4.

Table 7.4: Composition of the dried black peppe

Composition	Value in per cent
Moisture Content	8.7 – 14.1
Total Nitrogen	1.55- 2.60
Nitrogen in non volatile ether extract	2.7 – 4.22
Volatile ether extract	0.3 – 4.2
Non-volatile ether extract	3.9 – 11.5
Alcohol extract	4.4 – 12.0
Starch (acid hydrolysis)	28 – 49
Crude fibre	8.7 –18
Crude piperine	2.8- 9.0
Ash	3.6 –5.7

The ungarbled black pepper contains pinheads, immature pepper and large berries. Broken pepper and light pepper grades are separated pneumatically; pin heads which come along with garbled pepper are separated by sieving. As the export market potential for pepper is more, the market value can be increased by the removal of unwanted foreign materials.

Grading is done by a combination of size sieving and weight classification by air blast. The major grade is the average sized black pepper known as Malabar Garbled (MG), which constitutes 95% of India's export. Tellichery Garbled (TG) is another bold grade of black pepper. The recovery of black pepper from fresh berries is 33-36%. According to Agmark grading, grades have been formulated as given in Table 7.5.

Table 7.5: AGMARK specification of pepper

Pepper grade	Diameter (mm)
Tellichery Garbled Black pepper Special Extra Bold (TGSEB)	>4.75
Tellichery Garbled Extra Bold (TGEB)	4.25
Tellichery Garbled (TG)	4.0-4.25
Malabar Garbled Black Pepper (MG)	3.75
Malabar Ungarbled Black Pepper (MUG)	<3.75

Pungent principle

The alkaloid piperine (melting point 130^{o}C) is considered to be the major constituent responsible for pungency. It is not present in the leaves and stem. It is also not soluble in the water, readily soluble in alcohol and on hydrolysis splits into piperdine and piperic acids. Major adulteration in the black pepper is done with the papaya seeds. The best method to identify them is cut the seed in to two pieces. Papaya is a dicot, so it will show a line. Black pepper berries are monocot, have a hollow cavity in the center.

Processing of White Pepper

White pepper is the white inner corn obtained after removing the outer skin or pericarp of the pepper berries. It is preferred over black pepper in light-coloured preparations such as sauces, cream soups etc., whereas dark coloured particles are undesirable. White pepper imparts pungency and a modified flavour to food. White pepper is liked for its mellow flavour, mild pungency, low fiber, high starch content and above all the white colour itself is liked. Varieties like Balankotta and Panniyur-1, are ideal for making white pepper owing to their large sized berries. The composition of white pepper is given in Table 7.6.

Table 7.6: Composition of white pepper

Constituent	Water	Protein	Fat	Carbohydrate	Fiber	Ash
Content, (%)	11.4	10.4	2.1	68.6	4.3	1.6

Packaging

Black pepper berries are hygroscopic, so have to stored in cool, dry atmosphere away from sunlight. For retail packaging in 200 gauges HDPE pouches are used. Ground powder is packed in laminated heat sealed aluminium foil.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. In India, chilli is mainly dried by ……………………………………………...

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2. To get quality product of cardamom it should be dried with in ……………

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3. Pungent principal in the pepper is due to …………………………………...

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4. Main adulterant in the whole pepper is ……………………………………..

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7.3.6 Products and By-Products of Tamarind and their Uses

Tamarind is a forest tree. It is rarely grown as orchards. However, it is planted as social forestry. Every part of the tamarind is useful for human being as culinary or medicinal purposes.

Root: The root of tamarind is bitter and used in controlling the dysentery. It is cleaned, boiled and consumed or the powder is taken with water.

Stem bark: The stem bark is an astringent and a tonic. The bark is also used medicinally for loss of sensation in paralysis. The ash of the bark with salt is used as a remedy for colic and indigestion. A gargle of bark ash with water is used in sore throat to heal aphthous sores. The ash is given in urinary discharges and gonorrhea. The dry bark of the tree is peeled off for medicinal purposes. Usually it is done after the flowering season. The bark contains about seven percent tannin and is used in tanning industry.

Timber: The wood is hard, close-grained, yellowish white with red streak. The heartwood is small, near the center of the old trees and is dark purplish brown. It is a most valued timber for making tool-handles, agricultural implements, wheels, mallets, planks, furniture, rice-pounders, and oil and sugar crushers. It is also priced much higher as a fuel as it has high calorific value (4980) and chiefly used for making gun-powder, charcoal, and in brick kilns where great heat is required for brick-making.

Leaves: The tamarind leaves contain tartaric and malic acids. The latter is being found in excess and increasing with the age of the leaves. The leaves also contain certain enzymes. The leaves are astringent and the tender leaves are cooling and anti-bilious. A poultice of leaves is used as for inflammatory swellings and in rheumatism to relieve pain. Decoction of leaves is used for gargle, and juice is used in dysentery bilious fevers and in urinary troubles. The leaves yield a reddish yellow dye, which is used locally in colouring woollen and silk fabrics. The leaves and flowers are also used as auxiliaries in dyeing.

Flowers: The flowers of tamarind are also cooling and antibilious. Poultice of flowers is used in inflammatory affections of the conjunctiva. The juice extracted from flowers is used in cases of internal bleeding of piles.

Fruits: The fruits contain 55% pulp, 33.9% seeds and 11.1% shell and fiber. In India, the production of pulp is estimated at about 3,00,000 tons per year. Dry pulp of fruits yield about 16% of free tartaric acid and its salts along with Citric, Malic acids. Two kinds of pulp are known, the red coloured and the brown coloured. The former is having the superior quality. The pulp is non-proteinaceous and the pulp of tender fruits contains far less nitrogen than the ripe fruits. The pulp consists of crude protein 3.1%, carbohydrate 67.4%, fiber 5.6%, and minerals 2.9%. Chemical analysis of pulp give tartaric acid with potassium bi-tartarate 10-12%, moisture 20-30%, reducing sugars 25-30%, other solubles 3-4%, and the rest insoluble cellulose. Its vitamin contents are as follows: riboflavin 0.07mg, niacin 0.7mg and vitamin 'C' (3mg/100 g) and carotene (60 μ per 100 g). Of the reducing sugars present, about 70% is glucose and 30% fructose.

The pulp is edible and largely used for culinary purposes. The pulp contains tartaric acid, which is used as acidulent for soft drinks and fruit jellies. It is refrigerant, carminative and antibilious. It is also useful in preventing and curing scurvy and in sobering the intoxicating effects of alcohol and *Ganja (Cannabis sativa* Linn.). The pulp with wood-ash is extensively used for cleansing and brightening brass and copper vessels.

During storage, the reddish-brown colour of the pulp becomes darker and in about a year it is almost black. This is mostly due to the onset of Maillard reaction, since, free amino acids and reducing sugars are present in the pulp. The pulp also becomes soft and sticky as pectolytic degradation takes place and moisture is absorbed, especially in humid climates. The pulp could be preserved well for 6-8 months without any treatment, if packed in airtight containers and stored in cool and dry place.

Seeds: The seeds are used as famine food and for cattle in several districts in Tamil Nadu, Andhra Pradesh, Madhya Pradesh and elsewhere. The hard kernel is dried, roasted and powdered into flour and used for making cakes and chappatties, either alone or with flour of other edible kinds. The tamarind kernel powder can be fortified up to 15% in the preparation of bread and biscuit.

Industrial Uses

Tamarind Kernel Powder (T.K.P): Tamarind kernel powder is about 50% of the weight of the seeds. Commercial samples of T.K.P has the composition of : polysaccharides 48.7%, albuminoids 18.9%, fatty matters 7.5% moisture 8.8% ash 1.6%, soluble matters 3.2% and insoluble matters 11.3%. The commercial TKP finds extensive use as a sizing material in the textile industry. The sizing properties of TKP are due to the presence of a polysaccharide (called jellose) which is present to the extent of 6 percent.

7.3.7 Processing of Turmeric and its Uses

After harvesting the turmeric fingers are separated from mother rhizomes. Mother rhizomes are usually kept as seed material. Curing of green turmeric is done by boiling in the water with 20 g of sodium bi sulphite and 20 g of hydro chloric acid per 45.3 kg of tubers. It provides a yellow tint. The cured tubers are sun dried for 10-15 days till they become hard, brittle and produce metallic sound on breaking. Thereafter they are cleaned and then polished in a metallic drum rotated manually or by power. Generally dried cured turmeric is 20% of freshly harvested green rhizomes. It is also recommended that to develop attractive colour, half polished 100 kg turmeric rhizomes are mixed with the alum (0.040 kg), turmeric powder (2 kg), castor seed (0.14 kg), Sodium bisulphite (30 g) and concentrated hydrochloric acid (30 ml). After thoroughly mixing it is again dried in the sun.

Common products of turmeric are its powder, volatile oil and oleoresin. It is mainly used as food flavourant and colourant, cosmetics and as dye. It is used as medicine for stomachic, carminative, tonic, blood purifier, vermicide and antiseptic. Its powder is also used in tooth powder for relieving dental problem. It is also used as a face pack as it helps in clearing pimples and unwanted hairs.

7.3.8 Post Harvest Technology of Ginger

Freshly harvested ginger is cleaned with water to remove adhered soil, and then dried in the sun for 7-10 days. During drying, regular turning is required for uniform drying. After drying rhizomes are rubbed with the gunny bag to remove the remnants of the skin which results in smooth finish of the final product. In some places raw rhizomes are soaked in water and thick milk of lime (1kg slaked lime per 120 kg water). Some times the dried rhizomes are exposed to the sulphur dioxide fumes (3.2 kg of sulphur per tonne of rhizomes for 12 hours). It helps in bleaching the colour and results in white polished rhizomes.

The polished rhizomes are graded as per IS specification IS: 1908-1968. In general, indian ginger is graded in three grades namely (1) 3 fingerd rhizomes; (2) 2 fingered rhizomes and (3) pieces.

For the good quality of ginger its appearance, volatile oil content, fibre content, pungency, aroma and flavour are evaluated and compared with the standards.

In the rural India, ginger is heaped covered with the soil and ginger leaves in a shade. The heap may be plastered with the mud or cow dung. It can be stored well between 21-30^{o}C with 60-90 % relative humidity for two months. Scientifically ginger is stored in cold store at 2-5^{o}C with 90 % relative humidity for 4 months.

There various ginger products available in the market namely ginger oil, oleoresin, dehydrated ginger, bleached ginger, preserve, drinks, candy, pickle and wine. Besides this as a medicine it is considered as a stimulant and a carminative. It is also given in dyspepsia and flatulent colic.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the use of tamarind flower juice?

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2. Name the acid which tamarind pulp has?

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3. Why the tamarind pulp becomes black during storage? How it can be checked?

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4. What is the industrial use of TKP?

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5. What is the use of turmeric base face packs?

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7.4 MEDICINAL AND AROMATIC PLANTS

7.4.1 Uses of Medicinal and Aromatic Plants

Medicinal plants are the local heritage with global importance. Indian herbs are principal form of medicine and presently popular throughout the developed world. Basically herbs work in combination with the body's own defense system. The human body is much better suited to treatment with herbal remedies than with the isolated chemical medicines. The chemical medicines after expiry may cause harm to the body whereas the natural products that have lost their active qualities are not harmful to the system. The digestive systems and physiology of human evolved utilizing capacity of plant based foods and medicines. Many plants provide food as well medicines for i.e.

i) Lemon improves resistance to infections.
ii) Papaya is used for expelling worms in stomach.
iii) Onion relives bronchial infections.

iv) Oats support convalescence.
v) Burdock herbals are helping in removing toxins from the body.
vi) Comfrey encourages blood clotting and help in healing the wounds fast.

It also plays an important role in the rural areas, particularly in remote places with fewer medicinal facilities.

It is estimated that about 70000 plant species are used for medicinal purposes. In Ayurveda about 2000 plant species are considered to have medicinal values, while, Chinese list over 5700 as traditional medicines. The Indian traditional medicine the Charak Samhita (1000 BC) records the use of over 340 drugs of vegetables origin.

Medicinal plants have curative properties due to the presence of various complex chemical substances of different composition, which are found as secondary plant metabolites in one or more parts of these plants. The plant metabolites are grouped as alkaloids, glycosides, cortico steroids, essential oils etc. Table 7.7 indicates name of some herbs useful to cure some diseases.

Table 7.7: Medicinal use of herbs

System/Disease	Plant/Herbs	Uses
Skin		
(a) Antiseptic	Tea tree (Melaleuca attemifolia)	Disinfect the skin
(b) Emollients	Marigold (Calendula officinalis)	Deduce itchiness, edness and soreness
(c) Healing	Comfrey (Symphytum offcinale)	Blood cotting, fast healing of wounds
Respiratory system		
(a) Antiseptic	Garlic (Allium sativum)	Helps the lungs resist infection
(b) Spas molytics	Visnaga (Ammi visnaga)	Relax bronchial muscles.
Urinary system		
(a) Antispectic	Buchu (Barosma betulina)	Disinfect the urinary tubules
(b) Astringents	Horsetail (Equisetum arvense)	Tightness & protect the urinary tubules
Musculo-skeletalsystem		
(a) Analgesics	Yellow Jasmine (Gelsemium sempervirens)	Relieve joints and nerve pain
(b) Antiinflammatories	White willow (Salixalba)	Reduce swelling and pain in joints
(c) Antispasmodics	Cinchona (cinchona spp.)	Relax tense and cramped muscles.
Nervous system		
(a) Relaxants	Lemon balm (Melissa officinalis)	Relax nervous system

(b) Sedatives	Mistletoe (Viscum album)	Reduce nervous activity
(c) Stimulants	Kolanut (Colaacuminata)	Increase nervous activity
(d) Tonics	Oats (Avena Sativa)	Improve nerve function and tone
Circulation and heart		
(a) Cardiotonics	Ddanshen (Salvia mittiorrhiza)	Improve the regularity and strength of the heart contractions
(b) Circulatory stimulants	Cayenne (Capsicum frutescens)	Improve circulations of the blood to the extremities.
(c) Diaphoretics	Juhua (Chrysanthemum × morifolium)	Promote sweating & lower blood pressure
(d) Spasmolytics	Cramp bark (Viburmum opulus)	Relax the muscelers & helps to lower blood pressure
Digestive organs		
(a) Antiseptics	Ginger (Zingiber officinalis)	Protect against infections
(b) Astringents	Bistort (Polygenum bistorta)	Tighten the inner line of intestines and provide protecting coating over them.
(c) Bitters	Wormwood (Artemisia absinthum)	Stimulate secretion of digestive juices
(d) Laxatives	Senna (assia senna)	Stimulate bowel movements
(e) Stomachs	Cardamom (Eletterio cardamomum)	Protect and support

Aromatic plants have been of great interest to mankind from the beginning of civilization. Aromatic plants and their products, particularly the essential oil, are now becoming one of the most important export items from many developing countries. The upswing trends basically is due to raising the standard of living of the people and technological advancement in the production and processing of these essential oils.

Essential oils are complex mixtures of odours and steam-volatile compounds which are deposited by plants in the sub-cuticular space of glandular hairs, in cell organelles (oil bodies of Hepaticae), in idioblasts, in excretory cavities and canals or exceptionally in heartwoods.

The main aromatic plants are mint (mentha oil), cymbopogons. turpentine, sandal wood, vetiver, eucalyptus and ocimum. The other aromatic plants are celery, jasmine, rose, dill, geranium, hops, cinamomum, cedar wood, cyperus etc.

7.4.2 Processing of Medicinal and Aromatic Plants

The unit operations involving processing of plants based medicinal or aromatic constituents are:

1. **Comminution:** It is the process of size reduction. So that the surface area of the produce increases and solvent can easily interact with the produce. Most of the natural produce is to be dried. Drying can be done in sun or shade or in the protected area depending upon the type of the constituents. It is preferred that drying should be slow at low temperature. The dried material is to be crushed or broken into small parts before extraction/ distillation. During crushing/grinding temperature of the produce should not be increased. Some of the volatiles get evaporated even at 45^{o}C. The homogeneity of the ground particle shows the efficacy of the extraction of active ingredient

2. **Extraction of active ingredient:** Extraction is the process of separation of the active constituents from the plant material using a solvent. Firstly plant produce is pre-treated with the solvent outside the extractor. It facilitates the breaking of the cell walls to release the extractable component. The rate at which the solvent reacts with the solute depends upon solute solvent ratio, pH, particle size and temperature. Alcohol is the widely used solvent. It has the ability to extract many soluble constituents. Most of the alkaloids are soluble in acids.

For extraction of essential oil, steam distillation process in widely used. In this the steam is produced and passed through the bed of plant material. The steam carries the volatiles, which generally boils at a temperature lower than steam. It condenses and most of essential oils are insoluble in water. They are separated in the aqueous phase, forming two layers, then they can be easily separated. The factors, which influence the quality and quantity of extraction, are; size of load, steam pressure, density of packing of planting material in the bed, duration of distillation and rate of steam injection.

The aroma constituents are heat sensitive. So the technique must be carried out with pure and low boiling solvents such as pentane or hexane. Extraction with super critical solvents generally carbon-di-oxide is the most effective but capital intensive.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why herbal-based medicines are suitable to the human body?

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2. What is the need of comminution in the medicinal and aromatic plants?

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3. Efficacy of extraction mainly depends upon ………………………………

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7.5 LET US SUM UP

The knowledge of commercial crops, spices and medicinal and aromatic plants is necessary. It provides ample employment opportunity. India is known for its knowledge in their cultivation and quality processing since ages. Indians were deployed to other countries to teach cultivation of sugarcane. The merchants traded Indian spices many centuries ago. The ancient herbal medicines suits human bodies as they do not have any side effect.

The production, processing of each of the crop is different. The process technology depends up on the active constituent which is to be extracted. Its purity decides the price.

7.6 KEY WORDS

Molasses	:	A by-product of sugarcane industry and base material for distillery and fermented products.
H.S.C.	:	Highest Standard Count (HSC) is a unit to express and evaluate quality of the cotton.
Pungent principal	:	The main constituent responsible for pungency. For i.e. pepper it is alkaloid piperine.
T.KP.	:	Tamarind Kernel Powder (TKP) is the powder of dried tamarind kernel seeds. It is used as material in textile industry.
Essential oils	:	It is a complex mixture of odours and steam-volatile compounds, which are deposited by plants in the sub-cuticular space of glandular hairs, in cell organelles or in canals of woods.

Comminution : It is the process of size reduction of any substances so that surface area is increased.

Steam distillation : It is the process of boiling the substances with water, so that water soluble volatiles oils are carried away by the steam. Then steam is to be condensed so that oils being lighter can be easily separated.

7.7 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Sugarcane plant harnesses solar energy and converts it into sugar, cellulosic and non-cellulosic energy producing substances. So it is called as energy efficient crop.
2. It provides huge employment, produces lint as well as oil seed.
3. About 100 kg sugar
4. To avoid inversion of sugar.
5. It is diuretic, refreshing and cooling.
6. Digestion, washing, screening, bleaching, dewatering and thickening are the unit operations in paper manufacturing.

Check Your Progress Exercise 2

1. Fineness, maturity and strength are the indices to judge quality of cotton.
2. 27 mm and above
3. i) India ii) Cardamom iii) Pepper

Check Your Progress Exercise 3

1. Sun
2. 24-36 hours
3. Alkaloid piperine
4. Papaya seed

Check Your Progress Exercise 4

1. To check internal bleeding of piles.
2. Tartaric acid.
3. It is due to Millard reaction. It can be prevented by storing in airtight container at cool and dry place.
4. Tamarind kernel powder (TKP) is used in the textile industry.
5. It clears the pimples and unwanted hairs.

Check Your Progress Exercise 5

1. Herbal based medicines work in concert with the body's own defense system.
2. It increases the surface area so that solvent can easily interact with the active constitute.
3. Homogeneity of the product after comminution.

7.8 SOME USEFUL BOOKS

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UNIT 8 NUTRITIONAL ASPECTS

Structure

8.0 OBJECTIVES

After reading this unit, you should be able to:

- explain food, nutrition, nutrients, optimum nutrition, under nutrition, assessment of nutritional status;
- describe the role of different foods in our body;
- describe balanced diets; and
- state the importance of nutritional labelling.

8.1 INTRODUCTION

We need food for growth, development and to lead a healthy life. Since all foods are not of same nutritional quality, man's ability to meet his nutritional requirement depends upon the type and quantity of foodstuffs included in diet. It is not only the purchasing power of food but also the knowledge and awareness about nutritional needs at different stages of life, which is of paramount importance for maintaining nutritional health. We should consider the nutritive aspects of food from two broad points of view: first, what nutrients do foods contain and their requirement; and second, what are the relative stabilities of these nutrients and how are they affected by processing and handling. A brief description of general principles underlying the nutritional aspects is presented in the following sub-section.

8.2 SCOPE AND IMPORTANCE

We require more than 45 different nutrients throughout our life. Food materials ingested by our body are digested, absorbed and metabolized. A number of foodstuffs have to be selected to get all nutrients. Our health depends on the type and quantity of foodstuffs we choose in our diet. For sustaining healthy and vigorous life, diet should be planned according to the principles of nutrition.

Good nutrition is the fundamental basic requirement for health, functional efficiency and productivity. Good nutritional status is achieved not through drugs, tablets and pills but through a well and balanced diet. There is no known nutritional deficiency disorder that cannot be prevented by proper diet. Only the need is to provide adequate information to the common man as to how his nutritional needs can be fully met through judicious use of foods available at his own doorstep. The affluent sections need to be informed of the deleterious effects of dietary excesses and errors and how these can be avoided.

8.3 NEED FOR ENERGY

We need energy for work and different body functions. Whatever our age and sex, we need energy for three important functions of our body.

a) Basal metabolism
b) Physical activities
c) Dietary thermogenesis

a) Basal metabolism

The energy metabolism of a subject at complete physical and mental rest and having normal body temperature and in post absorptive state (i.e. 12 hours after the intake of last meal/ food) is known as basal metabolism.

b) Physical activity

Any movement of the body, or even a small part of it, expends energy. Greater the movement, higher the energy requirement. The actual amount of energy requirements of a person are determined by body weight, age, type and intensity of activity, and duration of activity.

Table 8.1: Effect of Body weight and type of physical activity on energy requirement (Kcal/day) of a moderately active person

Body weight (kg)	Men			Women		
	Light activity	Moderate activity	Very active	Light activity	Moderate activity	Very active
50	2100	2300	2700	1800	2000	2330
55	2310	2530	2970	2000	2200	2600
60	2520	2760	3240	2160	2400	2830
65	2700	3000	3500	2340	2600	3055
70	2940	3220	3780	2520	2800	3290

c) Dietary thermogenesis

Thermogenesis can be induced by diet, which is called as dietary thermogenesis, specific dynamic action or thermic effect of food. It is the amount of energy utilized by the body to digest, absorb, transport and store the nutrients. It is between 5-10% of the total energy intake. For example, it was found that in a fasting dog requiring 400 kcal, feeding of 100 g carbohydrates produces 425 Kcal, 44.4 g of fat produces 416 Kcal and 100 g of proteins produces 520 Kcal of heat. The extra heat produced is obtained by oxidation of tissue constituents and the animal will be in negative energy balance. This stimulating effect of carbohydrates, fats and proteins on energy metabolism is called specific dynamic action. The SDA of proteins is highest (about 30 %) while that of carbohydrates and fats is only 6% and 4% respectively.

8.4 BASAL ENERGY METABOLISM

Biochemical reactions (when body is at rest) are necessary to provide energy for maintenance of normal body temperature, breathing, heartbeat, muscle tone and other essential activities of cells and tissues. The basal metabolic rate is an expression of the amount of calories expended hourly in relation to the surface area of the body (calories/ meter^2/ hour).

Basal metabolic rate (BMR) is influenced by following factors:

Body surface area: A person who is tall and has greater proportion of lean tissues normally requires more basal energy than a shorter person of same weight.

Age: Age affects BMR because it changes the lean body mass especially the amount of muscle. BMR is highest during first 2 years of life due to rapid growth and declines about 2 % per decade after 21 years of age.

Gender: In general BMR of women is lower (about 6-10 %) than men due to higher body fat and other factors.

Pregnancy produces a BMR 15-25 per cent above the normal. Lactation also increases BMR.

Sleep: BMR during sleep is about 5-10 per cent less than in waking sate.

Environmental temperature: BMR increases when environmental temperature is low. At high temperature, BMR may decrease to lower heat production by the body.

Recent exercise: Following a period of exercise BMR remains elevated for some time.

Health factors: An elevation of body temperature above 98.6^0 F increases BMR by 7 per cent for each degree. Prolonged undernutrition, hypothyroidism, depression etc. tend to decrease BMR. Hyperthyroidism, anger, fear and other strong emotions increase BMR.

8.5 ENERGY VALUE OF FOODS

The energy yielding food factors are carbohydrates, proteins and fats. Vitamins and minerals do not provide energy, although they take part in liberating energy. Within the body, nutrients providing energy are oxidized in the cells with the help of catalysts. The process is one of continuous utilization of oxygen and production of CO_2, water and heat:

$$\text{Carbohydrates and fats} \xrightarrow{O_2} CO_2 + \text{water} + \text{heat}$$

$$\text{Proteins} \xrightarrow{\text{Oxidation}} CO_2 + \text{water} + \text{urea}$$

The energy value of foods depends on the quantity of carbohydrates, fats and proteins present in them. This can be determined by oxidizing a known weight of food in an instrument called bomb calorimeter and measuring the heat produced. The energy value of foods can be expressed in terms of kilocalories (Kcal) or mega joules (MJ).

One kilo calorie = 4.186 kilo joules
1000 kilo calorie = 4.186 × 10^3 kilo joules or 4.186 mega joules
1 Mega joule = 1000 kilo joules
1 Mega joule = 239 Kcal
1 Kilo calorie = 4.186 kilo joules

Addition of ghee or oil or butter to a food during preparation will increase the calorie content of that food. The average calorific value of pure carbohydrates, fats and proteins determined using the bomb calorimeter are:

1 g carbohydrates	4.1 Calorie
1 g fats	9.45 Calorie
1 g proteins	5.65 Calorie

The physiological energy value of carbohydrates, fats and proteins are 4,9,4 after making allowances for losses in digestion and metabolism.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand by nutrition? Write the importance of different nutrients in our body in brief.

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2. Why do we need energy? Explain.

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3. Define basal energy metabolism. What do you understand by basal metabolic rate?

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8.6 NUTRITIVE VALUE OF FOODS

Foods can be broadly classified into (i) cereals and millets (ii) legumes and pulses (iii) oilseeds and nuts (iv) vegetables (v) fruits (vi) fats and oil (vii) egg, meat, fish and other animal foods (viii) milk and milk products (ix) starchy and sugary foods and (x) spices and condiments.

Cereal and millets

Cereals are the main source of energy in our diet. They contribute 70-80% of daily energy intake of majority of Indians. They also contribute significant quantities of proteins, calcium, and vitamin B complexes. Cereal proteins are deficient in an essential amino acid lysine. However, if supplemented with pulses rich in lysine, biological value of cereal products increases.

Cereals contain invisible fat that can meet more than 50 percent of our essential fatty acid requirement. Cereals are also fair source of calcium and iron. Ragi is rich in minerals especially calcium. Millets including ragi are rich in minerals and fibre. Millets are also rich in phytate and tannin, which bind minerals and hence interfere with their bioavailability. Cereals do not contain either vitamin C or vitamin A except that yellow maize and some varieties of sorghum contain small amounts of β-carotene.

Legumes and pulses

Pulses are rich source of protein but do not contain vitamin C. They are a good source of B vitamins also. Germinated legumes are good source of vitamin C. Fermentation also improves the nutritive value particularly thiamin and niacin are enhanced. Legumes and pulses are also deficient in vitamin A, D, and B_{12}.

Khesari dhal, consumed in some parts of the country may cause lathyrism if the consumption is more than 300 gm/day for 6 months.

Table 8.2: Nutrients content of some commonly used cereals, legumes & nuts (values/ 100 g)

Particulars	Calories (Kcal)	Protein (g)	Fat (g)	Fibre (g)	Calcium (mg)	Iron (mg)	Carotene (µg)
Bajra or pearl millet	360	11.6	5.0	1.2	0.05g	8.8	132
Barley	335	11.5	1.3	3.9	0.03g	3.7	10
Maize, dry	342	11.1	3.6	2.7	10	2.3	90
Rice (raw, milled)	345	6.8	0.5	0.2	10	0.7	-
Rice, puffed	325	7.5	0.1	0.3	23	6.6	-
Whole wheat flour	341	12.1	1.7	1.9	48	4.9	-
Wheat bread, white	245	7.8	0.7	0.2	11	1.1	-
Bengal gram, whole	360	17.1	5.3	3.9	202	4.6	189
Bengal gram dhal	372	20.8	5.6	1.2	56	5.3	129
Black gram dhal	347	24.0	1.4	0.9	154	3.8	38
Rajmah	346	22.9	1.3	4.8	260	5.1	-
Red gram dhal	335	22.3	1.7	1.5	73	2.7	32
Almond	655	20.8	58.9	1.7	230	5.09	0
Coconut dry	662	6.8	62.3	6.6	400	7.8	0
Gingelly seeds	563	18.3	43.3	2.9	1450	9.3	60
Groundnut	567	25.3	40.1	3.1	90	2.5	37

Source: Nutritive value of Indian Foods, 1991.

Nuts and oilseeds

Nuts and oilseeds (except coconut) are rich in proteins containing about 18-40 per cent. Soybean is the richest source in proteins (containing about 40 per cent). They do not contain much carbohydrates but are rich in B-vitamins. Groundnuts are particularly rich in thiamin and niacin. Sesame seeds are rich in calcium.

Fats and oils

Fats and oils provide energy; vitamin A, E, D and K. Vegetable oils contain vitamin E and essential fatty acids (viz. linoleic and linolenic acids) except coconut and palm oils. Vegetable oils do not contain vitamin A and D except red-palm oil, which is exceptionally rich in carotene, a precursor of vitamin A.

Table 8.3: Nutritive values of fats (per 100 g)

Particulars	Moisture (%)	Fat (%)	Energy (Kcal)	Vitamin A (I.U.)	Vitamin E (mg)
Butter	14	86	774	700	2.4
Ghee	-	100	900	600	2.0
Vegetable oils and fats	-	100	900	-	8-140
Red palm oil	-	100	900	4000-10,000	10-15
Margarine#	14	86	774	700	10-50
Vanaspathi#	-	100	900	700	10-30

Processed fat

Vegetables

Vegetables are termed as 'protective foods' due to their high vitamins and mineral content. These generally have high water content, low protein and energy and varying amount of dietary fibre. Vegetables can be broadly grouped into green leafy vegetables, roots and tubers, and other vegetables. Green leafy vegetables are good source of calcium, iron, carotene, dietary fibre, vitamin C and vitamin B-complexes except vitamin B_{12}.

Table 8.4: Nutritional compositions of green leafy vegetables

Constituents	Range of values (per 100 g)
Moisture (g)	79-92
Energy (Kcal)	32-96
Carbohydrates (g)	4-14
Proteins (g)	109-607
Fat (g)	0.1-1.7
Calcium (mg)	30-500
Iron (mg)	0.8-16.0
Carotene (μg)	1200-7500
Vitamin C (mg)	48-200
Thiamin (mg)	0.05-0.16
Riboflavin (mg)	0.11-0.34
Nicotinic acid (mg)	0.4-1.8
Folic acid (mg)	10-30
Total dietary fibre (g)	2-6

Roots and tubers are rich in carbohydrates mainly starch and provide energy. In general, these are poor in proteins, vitamin and minerals but carrot and yellow flesh variety of sweet potato, and yellow yam are good sources of carotene. Potato is a fair good source of protein and vitamin C. Tapioca and yam are rich in calcium. Other vegetables (brinjal, okra, beans, all gourds, pumpkin, etc) not only provide variety to the diet but also provide vitamin C, some minerals, and fibre and thus add bulk to the diet.

Fruits

Fruits are priced for their vitamin and minerals content. Amla (600 mg/ 100g), guava (212 mg/ 100g) are rich source of vitamin C. Some fruits like banana and mango provide high calorie because of high sugar content. Eating fruits raw and fresh makes the vitamins and minerals present in them easily available to the body. Dried fruits like raisins, dates and apricots are good source of iron and calcium. Fruits also contain dietary fibre.

Foods from animal origin

Milk is almost a complete and ideal food. Milk and milk products like paneer, curd, khoa, etc. are good source of proteins, calcium, riboflavin and vitamin B_{12} but very poor in iron and vitamin C content. Milk does not contain vitamin E.

Eggs contain all nutrients except vitamin C and dietary fibre. Eggs contain proteins of very high biological value. Egg white contains about 12% proteins and some of B-vitamins but is devoid of fat and vitamin A. Egg yolk contains about 15% proteins, 3% fat, rich in vitamin A, iron, B-vitamins and vitamin D.

Flesh foods like meat, poultry and fish are rich in good quality proteins (18-22%) and vitamin B-complexes. Meat does not contain vitamin A, C and D. Fatty fish contain some vitamins A and D. Liver is rich in vitamin A and richest source of vitamin B_{12}.

Table 8.5: Nutritive value of some commonly used foods of animal origin (values/ 100 g)

Particulars	Calories (Kcal)	Protein (g)	Fat (g)	Calcium (mg)	Iron (mg)	Carotene (μg)
Milk (cow's)	67	3.2	4.1	120	0.2	174
Curd (cow milk)	60	3.1	4.0	149	0.2	102
Egg (hen)	173	13.3	13.3	60	2.1	600
Mutton (muscle)	194	18.5	13.3	150	2.5	0
Pork (muscle)	114	18.7	4.4	30	2.2	0

Other foods

Foods like sugar, jaggery, glucose, honey, custard powder, sago etc. mainly contain carbohydrates and provide energy.

Condiments and spices are accessory foods used for flavouring purposes to enhance the palatability of products. These are used in small amounts and their contribution to nutrient intake is very limited.

8.7 FOOD PYRAMID

The food pyramid is an outline to show the groups of foods that make a balanced diet. It is a general guideline that lets you choose a variety of foods from different food groups to get the various nutrients in right proportions. Its pyramid shape helps to explain which foods should be eaten more or less. The foods that make up the base of the pyramid i.e. widest part should provide the bulk of our diet. As you go up the pyramid, the amounts of different foods get smaller. Each of these food groups provide some, but not all, of the nutrients we need. Foods in one group can't replace those in another. No one-food group is more important than another - for good health, we need them all. The USDA has made some recommendation and provides a set of guidelines for healthy eating, represented in Figure 8.1.

Figure 8.1: Food pyramid

New guidelines emphasise more as weight control, whole grains, plant oils, vegetables & fruits and less on consumption of red meat, butter and refined foods such as white rice, white bread, pasta, etc.

8.8 DIGESTIVE PROCESS

Food do not get absorbed into the body as such except only a few substances namely water, simple sugars and some of mineral salts and vitamins. The principal component of food namely carbohydrates, fats and proteins undergo digestion.

8.8.1 Digestion of Carbohydrates

Digestion of cooked starch by salivary amylase begins in the mouth. This continues in the stomach for 10-15 minutes, till the food get mixed with gastric juice and action of amylase ceases due to high acidity.

A greater part of starch and glycogen present in food is digested by pancreatic amylase in small intestine.

- Starch and glycogen $\xrightarrow{\text{Pancreatic amylase}}$ Maltose + Isomaltose
- Sucrose $\xrightarrow{\text{Sucrase}}$ Glucose + Fructose
- Maltose $\xrightarrow{\text{Maltase}}$ 2 molecules of glucose
- Lactose $\xrightarrow{\text{Lactase}}$ Glucose + Galactose
- Isomaltose $\xrightarrow{\text{Isomaltase}}$ 2 molecules of glucose

The resulting monosaccharides viz. glucose, fructose, galactose are absorbed in small intestine. Cellulose, hemicellulose, pectin etc. are not digested and excreted as such.

8.8.2 Digestion of Proteins

Hydrolysis of proteins is accomplished by proteases secreted in gastric juice, pancreatic juice and in the small intestine.

Gastric digestion: The proteolytic enzyme present in gastric juice is pepsin. Since food remains in stomach for short time, pepsin hydrolyses dietary proteins mainly into a mixture of polypeptides.

Dietary protein $\xrightarrow{\text{Pepsin}}$ Polypeptides

Digestion in small intestine: The main digestion of polypeptides produced in stomach takes place in small intestines. The proteases involved in digestion are trypsin, chymotrypsin and carboxypeptidase secreted in pancreatic juice and amino peptidases present in intestinal mucosa.

- Protein and Polypeptides $\xrightarrow{\text{Trypsin and Chymotrypsin}}$ Peptide + amino acids
- Peptides $\xrightarrow{\text{Carboxy peptidase}}$ Amino acids
- Peptides $\xrightarrow{\text{Amino peptidases}}$ Amino acids
- Dipeptides $\xrightarrow{\text{Dipeptidase}}$ Amino acids
- Tripeptides $\xrightarrow{\text{Tripeptidases}}$ Amino acids

The resulting amino acids are absorbed in small intestine.

8.8.3 Digestion of Fat

Almost all fats present in our meal are triglycerides. Only a small fraction of dietary fat consists of cholesterol esters and phospholipids. Fats are primarily hydrolyzed in the small intestine. In stomach gastric lipase brings about some hydrolysis of finely divided fats only such as egg yolk and cream. Brief description of digestion and absorption of fat is given below.

Reaction in intestinal lumen	**Reaction within intestinal wall**	**Mode of entry into circulation**
Fat (Triglyceride) — 3-10% absorbed as micelle →	Triglycerides and diglycerides may be hydrolysed by intestinal lipase into monoglycerides & fatty acids	Lymphatic vessels (lacteals)
↓ Lipase		
Diglycerides + fatty acids — 3-10% absorbed as micelle →		
↓ Lipase		
Monoglycerides + fatty acids — 60-68% absorbed as micelle →	Resynthesis of neutral fat, Phospholipids and cholesterol esters and formation of chylomicrons	
↓ Lipase		
Glycerol+ fatty acids — 20% absorbed as micelle		
Phospholipids		
↓ Phospholipase		
Glycerol + fatty acids + phosphoric acid + organic base — (choline etc.) Absorption →		
Cholesterol esters		Portal blood
↓ Cholesterol esterase		
Cholesterol + fatty acids — Absorption →		
Short chain fatty acids (C_4-C_{10}) — Absorption →	Short chain fatty acids (C_4-C_{10}) →	Short chain fatty acids (C_4-C_{10})
→ Glycerol — Absorption →	Glycerol →	Glycerol

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are different foods? Write the importance of fruits and vegetables.

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2. Define food pyramid. What is the importance of food pyramid in food selection for the diet?

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3. Explain the term 'digestion'. Write the different enzymes, which are important for digestion of carbohydrates, proteins and fats.

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8.9 DIETARY ALLOWANCES, STANDARDS AND BALANCED DIETS FOR DIFFERENT AGE GROUPS: CHILDREN, ADULTS, PREGNANT AND LACTATING WOMEN, OLD PEOPLE

8.9.1 Dietary Allowances and Standards

Dietary allowances are measures of nutritional need in terms of specific amount of nutrients that a person should receive every day to achieve full growth and development potential. The Nutrition Advisory Committee of Indian Council of Medical Research (1989) recommended the dietary allowances of different nutrients, which are presented in Table 1.11. Reference man is between 20-39 years of age, weighs 60 kg, free from diseases and physically fit for active work. Reference woman is between 20-39 years, weighs 50 kg and healthy.

8.9.2 Balanced Diets for Different Age Groups

A balanced diet is one which includes a variety of foods in such quantities and proportion that the need for nutrients is adequately met to promote and maintain the health. Food requirement will differ according to age, sex, physical activity, and physiological state viz. pregnancy, lactation etc.

Balanced diets for different age groups, sex, moderate activity and physiological state are given in Table 8.6 to 8.10. These diets are formulated using food exchange system suggested by Gopalan et al. (1991) and recommended dietary allowances of nutrients for Indians (I.C.M.R, 1989).

The food stuffs given in these tables should be considered as raw food items that represent a food group, for example, cereals may include wheat, bread, rice, puffed rice, maize etc. depending upon the dietary habits of individual/ family.

Mother's milk is the best food for newborns and infants up to 6 months of age. Afterwards, supplementary foods along with milk, is necessary. Strained fruit juices and soups, mashed banana, papaya, sago porridge, rice porridge, soft boiled egg yolk, mashed and well cooked khitcheri etc. may form the supplementary foods for the infants.

Table 8.6: Balanced diets for children (1-9 years old)

Food stuffs (g/caput/day)	**1-3 years**		**4-6 years**		**7-9 years**	
	Veg.	**Non-veg.**	**Veg.**	**Non-veg.**	**Veg.**	**Non-veg.**
Cereals	120	120	200	200	250	250
Pulses	20	20	40	40	50	50
Green leafy vegetables	50	50	50	50	50	50
Other vegetables	30	30	50	50	75	75
Fruits	50	50	50	50	100	100
Milk*	400	300	400	300	400	300
Fats and oils	20	20	20	20	25	30
Sugar and jaggery	20	20	40	40	30	30
Eggs or meat	-	50	-	50	-	50
Approximate nutrients						
Carbohydrates	158	153	256	251	334	284
Proteins	34	36	47	49	53	57
Total fats	46	46	46	46	41	56
Energy (kcal)	1258	1228	1689	1659	1933	1946

*Buffalo milk. If cow milk is to be taken, increase the amount by one and half times

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Table 8.7: Balanced diet for boys

Food stuffs (g/caput/day)	10-12 years		13-15 years		16-18 years	
	Veg.	Non-veg.	Veg.	Non-veg.	Veg.	Non-veg.
Cereals	300	300	350	350	390	390
Pulses	50	50	50	50	60	60
Green leafy vegetables	75	75	100	100	100	100
Other vegetables	75	75	100	100	100	100
Fruits	100	100	50	50	50	50
Milk	400	300	400	300	400	300
Fats and oils	30	30	30	30	30	30
Sugar and jaggery	40	40	25	25	30	30
Groundnut	25	25	25	25	25	25
Eggs or meat	-	60	-	60	-	60
Approximate nutrients						
Carbohydrates	394	345	381	376	423	367
Proteins	58	63	71	75	77	83
Total fats	43	57	66	67	66	86
Energy (kcal)	2189	2182	2451	2437	2640	2635

Table 8.8: Balanced diets for girls

Food stuffs (g/caput/day)	10-12 years		13-18 years	
	Veg.	Non-veg.	Veg.	Non-veg.
Cereals	250	250	250	250
Pulses	50	50	50	50
Green leafy vegetables	75	75	150	150
Other vegetables	50	50	100	100
Fruits	100	100	50	50
Milk	400	300	400	300
Fats and oils	30	30	25	25
Sugar and jaggery	30	30	25	25
Groundnut	25	25	25	25
Eggs or meat	-	60	-	60
Approximate nutrients				
Carbohydrates	298	293	303	299
Proteins	54	28	61	64
Total fats	56	57	51	62
Energy (kcal)	1972	1959	2083	2070

Table 8.9: Balanced diet for adult man & woman (moderate worker)

Food stuffs (g/caput/day)	Man		Woman			
	Veg.	Non-veg.	Veg.	Non-veg.	Pregnancy*	Lactation*
Cereals	490	490	350	350	-	25
Pulses	60	50	50	40	25	25
Green leafy vegetables	100	100	150	150	50	-
Other vegetables	100	100	100	100	-	-
Fruits	100	100	100	100	50	50
Milk	300	200	300	200	200	200
Fats and oils	40	40	30	30	-	10
Sugar and jaggery	40	40	25	25	-	10
Eggs or meat	-	90	-	90	-	-
Approximate nutrients						
Carbohydrates	507	496	377	366	38	60
Proteins	76	82	60	65	14.5	17
Total fats	59	65	49	55	13	23
Energy (kcal)	2871	2858	2228	2215	357	554

* additional allowances (in addition to normal diet) during pregnancy/ lactation

Table 8.10: Balanced diet for an aged person (60-70 years)

Food stuffs (g/caput/day)	Man		Woman	
	Veg.	Non-veg.	Veg.	Non-veg.
Cereals	325	325	225	225
Pulses	50	50	50	50
Green leafy vegetables	100	100	100	100
Other vegetables	150	150	150	150
Fruits	200	200	200	200
Milk	300	200	300	200
Fats and oils	20	20	20	20
Sugar and jaggery	20	20	20	20
Eggs	-	50	-	50
Meat	-	30	-	30
Approximate nutrients				
Carbohydrates	363	358	283	278
Proteins	58	63	48	53
Total fats	40	42	40	42
Energy* (kcal)	2084	2087	1744	1747

*Due to reduced basal Metabolic Activities, energy requirement in this age group is reduced by 20 per cent

Table 8.11: Recommended dietary allowances for Indians

Group	Particulars	Body wt. (kg.)	Energy kcal/d	Protein g/d	Fat g/d	Ca mg/d	Iron mg/d	Vit.A µg/d	Thiamin mg/d	Riboflavin mg/d	Niacin mg/d	Pyri-doxin mg/d	Vit.C mg/d	Folic acid mg/d	Vit.B mg/d
Man*	SW	60	2425	60	20	400	28	600	1.2	1.4	16	2.0	40	100	1
	MW	60	2875	60	20	400	28	600	1.4	1.6	18	2.0	40	100	1
	HW	60	3800	60	20	400	28	600	1.6	1.9	21	2.0	40	100	1
Woman*	SW	50	1875	50	20	400	30	600	0.9	1.1	12	2.0	40	100	1
	MW	50	2225	50	20	400	30	600	1.1	1.3	14	2.0	40	100	1
	HW	50	2925	50	20	400	30	600	1.2	1.5	16	2.0	40	100	1
	Pregnancy		+300	+15	30	100	38	600	+0.2	+0.2	+2	2.5	40	400	1
	Lactation														
	0-6 months		+550	+25	45	1000	30	950	+0.3	+0.3	+4	2.5	80	150	1.5
	6-12months		+400	+18	45	1000	30	950	+0.2	+0.2	+3	2.5	80	150	1.5
Infants	0-6 months	5.4	108/kg	2.05 kg		500	-	-	55µg/kg	65µg/kg	710 µg/kg	0.1	25	25	0.2
	6-12months	8.6	98/kg	1.65/kg	-	500	-	350	50µg/kg	60µg/kg	650 µg/kg	0.4	25	25	0.2
Children	1-3 years	12.2	1240	22	25	400	12	400	0.6	0.7	8	0.9	40	30	0.2
	4-6 years	19.0	1690	30	25	400	18	400	0.9	1.0	11	0.9	40	40	1.0
	7-9 years	26.9	1950	41	25	400	26	600	1.0	1.2	13	1.6	40	60	
Boys	10-12 years	35.4	2190	54	22	600	35	600	1.1	1.3	15	1.6	40	70	0.2-1.0
Girls	10-12 years	31.5	1970	57	22	600	19	600	1.0	1.2	13	1.6	40	70	0.2-1.0
Boys	13-15 years	47.8	2450	70	22	600	41	60	1.2	1.5	16	2.0	40	100	0.2-1.0
Girls	13-15 years	46.7	2060	65	22	600	28	600	1.0	1.2	14	2.0	40	100	0.2-1.0
Boys	16-18 years	57.1	2640	78	22	500	50	600	1.3	1.6	17	2.0	40	100	0.2-1.0
Girls	16-18 years	49.9	2060	63	22	500	30	600	1.0	1.2	14	2.0	40	100	0.2-1.0

* Reference man/ woman

8.10 TECHNIQUES FOR ASSESSMENT OF HUMAN NUTRITION

The nutritional status of an individual is influenced by food intake both in terms of quantity and quality and also by physical health of the person. The main objective of nutritional assessment is to obtain precise information on prevalence and geographical distribution of nutritional problems of a given community and identifying the individuals or groups of people 'at risk' or in a greatest need of nutritional assistance.

The assessment of nutritional status involves various techniques viz. clinical examination, anthropometry, biochemical evaluation, assessment of dietary intake, vital and health statistics, ecological studies.

Clinical Assessment of Nutritional Status

There are a number of physical signs, some specific and many non-specific known to be associated with states of malnutrition. Clinical signs, which are useful in assessment of nutritional status are: moon face, angular stomatitis, xerosis of conjuctiva, Bitot's spots, magenta tongue, etc. However, malnutrition cannot be quantified on the basis of clinical signs and many deficiencies are unaccompanied by physical signs.

Anthropometric Measurements

Anthropometric measurements such as height, weight, skin fold thickness and arm circumference are valuable indicators of human nutrition. In young children, additional measurements such as head and chest circumference are good indicators.

Laboratory and Biochemical assessment

Haemoglobin estimation is, most common laboratory test carried out to assess the prevalence of anaemia. Stools are examined for intestinal parasites. Urine is examined to assess the presence of albumin and sugar, etc.

Biochemical tests are applied to measure nutrient concentration in body fluids (e.g. serum iron, serum albumin, etc.) or detection of abnormal amounts of metabolites in urine (e.g. urinary creatinine, etc.) or measurement of enzymes in which the vitamin is a known co-factor (as in riboflavin deficiency) to assess malnutrition in its preclinical stages.

Radiological and Biophysical Assessment

Radiological examination may help in diagnosis of rickets, osteomalacia, infantile scurvy, beriberi, fluorosis, and protein-calorie malnutrition.

A large number of tests have been devised to assess dark adaptations of the eye, nerve accommodation, physical performance, muscle co-ordination etc., in different deficiency states to assess the degree of alteration in physiological function.

Assessment of Dietary Intake

Assessment of food consumption involves dietary surveys, which may be household inquiries, or individual food consumption surveys. A diet survey may be carried out by one of the methods viz. weighment of raw foods, weighment of cooked foods, oral questionnaire method to get information about dietary intake patterns; specific food consumed and estimated nutrient intakes.

Vital Statistics

An analysis of vital statistics – mortality (infant mortality rate, rate of low birth weight babies etc.) and morbidity data (hospital data or data from community health and morbidity surveys) particularly protein energy malnutrition, anaemia, xeropthalmia and other vitamin deficiencies, endemic goiter, diarrhoea, measles and parasitic infestations can be of value in providing additional information contributing to nutritional status of the community.

Ecological Studies

Malnutrition is the end result of many interacting ecological factors. A study of ecological factors comprises of food balance sheet, socio-economic factors (family size, occupation, income, education, customs, cultural influences etc.), health and educational services (primary health care services, feeding and immunization programme), and conditional influences (e.g., parasitic, bacterial and viral infections etc.).

8.11 NUTRITIONAL LABELLING

Labelling for nutrition information has been mandatory for (i) any food to which a nutrient has been added – enrichment, fortification, or restoration and (ii) any food for which a claim is made for nutritional properties either on the label or in advertising. All food for special dietary use require labelling. At present most nutrition labelling is voluntary, but many manufacturers have adopted it for their products.

Reasons for nutrition labelling:

- The main reason for nutrition labelling is to make the consumer aware about the nutritional properties of the product.
- Labelling also leads food processors to be constantly aware of the nutritive values of foods that they produce.
- Labelling will help persons who require modified diets to select those foods appropriate for their needs.

Regulations for nutrition labelling established by the Food and Drug Administration (FDA) are presented in Figure 8.2.

NUTRITION INFORMATION
(PER SERVING)
SERVING SIZE = 8 OZ.

SERVINGS PER CONTAINER = 1

CALORIES…………..….560	FAT (PERCENT OF CALORIES 53%)….……..33 GM
PROTEIN ……..…………23 GM	POLYUNSATURATED*...2 GM
CARBOHYDRATE …….43 GM	SATURATED …………….9 GM
	CHOLESTEROL* (20 MG/100 GM)…………40 GM
	SODIUM (365 MG/ 100 GM) …………………830 MG

PERCENTAGE OF U.S. RECOMMENDED DAILY
ALLOWANCES (U.S. RDA)

PROTEIN ………………………..…35	RIBOFLAVIN …….…..15
VITAMIN A …………………….…35	NIACIN ……………..….25
VITAMIN C (ASCORBIC ACID)…………….10	CALCIUM……………..…..2
THIAMIN (VITAMIN B_1) ……. 15	IRON …………………..…25

*Information on fat and cholesterol content is provided for individuals who, on the advice of a physician, are modifying their total dietary intake of fat and cholesterol

Figure 8.2: The nutrition label format (U.S. FDA)

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand by dietary allowances? Write the requirements of fruits and vegetables in our daily diet.

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2. List the various techniques involves in assessment of nutritional status. What are various anthropometric measurements?

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3. Nutritional labelling helps the consumer in products selection. Justify.

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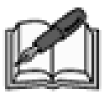
8.12 LET US SUM UP



Food is essential for our health and vitality. It is the food that provides us nourishment to perform various voluntary and involuntary functions of our body and prevents from deficiency diseases. Purchasing power of food and nutritional knowledge and awareness about nutritional need are the most important factors that affect the dietary consumption and nutritional health of a person and of any community.

It is the food pyramid which is a good guide in choosing a variety of foods from different food groups to get the required nutrients. Nutritional labelling also makes us aware about nutritional properties of purchased products.

8.13 KEY WORDS

Absorption : Transfer of nutrients across cell membranes; following digestion, nutrients are transferred from the intestinal lumen across the mucosa and into the blood and lymph circulation.

Digestion : Hydrolysis of foods in the digestive tract to simpler substances so that they can be used by the body.

Health : State of complete physical, mental and social well being and not just absence of disease.

Kilo Calorie : Kilo Calorie is the quantity of heat required to raise the temperature of 1 kg of water through 1^0C.

Metabolism : Physical and chemical changes occurring within the organism; includes synthesis of biological materials and breakdown of substances to yield energy.

Enzyme : An organic compound which can be protein or RNA produced by living tissue to accelerate certain specific metabolic reactions, viz. hydrolases, oxidases, peptidases and others.

Cholesterol : The commonest member of sterol group; synthesize by body and is essential for its functions.

8.14 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. We need nourishment to perform various voluntary and involuntary body functions.

   The nutrients; carbohydrates, proteins, fats, vitamins and mineral are required by body to provide energy, development of body tissue, bones, teeth etc. See Sub-sec. 8.1, 8.2 and 8.5.

2. Basal metabolism

   Physical activities

   Dietary thermogenesis. See Sub-sec. 8.

3. Some of the energy is required at rest.

   Basal metabolic rate is the amount of calories required in the state of complete rest.

   Basal metabolic rate is influenced by body surface area, gender, age, health factors, sleep etc. See Sub-sec. 8.4

Check Your Progress Exercise 2

Your answer should include the following points:

1. Broadly foods can be classified in to ten different groups.
   Fruits and vegetables are termed as protective foods.
   Fruits and vegetables provide vitamins and minerals. See sub-sec. 8.6.

2. Food pyramid shows the food groups.
   Food pyramid helps in selecting balanced amount of foods. See sub-sec. 8.7

3. Hydrolysis of food is essential for absorption of different nutrients. Amylase, proteases, lipase etc. are enzymes essential for digestion of food. See sub-sec. 8.10.

Check Your Progress Exercise 3

Your answer should include the following points:

1. Dietary allowances are measures of nutrients that we need to take daily.

   An amount of 100 g of each of fruits, green leafy vegetables and other fruits can fulfil our daily requirements. See sub-sec. 8.9.2. and Tables 8.1 to 8.5.

2. Clinical examination, anthropometry, biochemical evaluation, assessment of dietary intake, vital and health statistics, ecological studies are techniques for nutritional assessment.

   Important anthropometric measures are height, weight, skin fold thickness, arm circumference, head and chest circumference. See sub-sec. 8.10.

3) Nutritional labelling is helpful in selecting nutritious products from variety of available products.

   FDA has established regulations for nutrition labelling. See sub-sec. 8.11

8.15 SOME USEFUL BOOKS

1. Gopalan, C. and Shastri, Rama, Balasubramanian, S.C. (2002) Nutritive Value of Indian Foods, National Institute of Nutrition, ICMR, Hyderabad, India.

2. Mridula, D. and Bisht, B.S. (2000) Food Facts and Diets, Central Institute of Post Harvest Engineering and Technology, Ludhiana, India.

3. Mudambi, S.R. and Rajagopal, M.V. (1982) Fundamental of Foods & Nutrition (Third Edition), Willey Eastern Limited, New Delhi.

4. Swaminathan, M. (1991) Advanced Text Book on Food and Nutrition Volume I, Bangalore Printing and Publishing Company, Bangalore.

5. Swaminathan, M. (1991) Advanced Text Book on Food and Nutrition Volume II, Bangalore Printing and Publishing Company, Bangalore.

UNIT 9 FOOD FOR GROWTH AND REPAIR

Structure

9.0 OBJECTIVES

After reading this unit, you should be able to:

- describe the effect of processing and storage on food quality and how to prevent them;
- state safe limit of preservatives; and
- discuss the health foods.

9.1 INTRODUCTION

Each food, although contains a wide range of nutrients but serves as a major source of one or two main nutrients. Since each food has a different nutritional profile, a judicious use of different foods is desired to maintain good health. The health of an individual is influenced by the utilization of nutrients, called nutritional status. The application of knowledge of nutrition in selecting food, its combination, preparation, storage, physiological need, nutritional knowledge; all affects the overall nutrition of a person and the community.

Food occupies the first position in the hierarchical needs of man but ignorance of basic food facts is still widespread. Consequently, various forms of nutritional disorders results, that can be prevented by proper dietary counselling. There is no known nutritional deficiency disorder that cannot be prevented by appropriate dietary habits. Only the need is to lay adequate emphasis to this fact and to provide adequate nutritional information to all of us. Food-based approach is the only sustainable way to improve the nutritional status of all.

It is not only the foods but also the quality of foods which is of prime importance for us. Foods if not processed properly, may loose their nutritive properties. Even if stored under improper storage condition or handled carelessly, they may get contaminated with microorganisms. Hence, for proper storage of fresh produce to retain their freshness, nutritive value and acceptability, proper handling, transport and storage of fresh or processed products is of great importance.

9.2 IMPORTANCE OF FOOD FOR GROWTH AND SUSTENANCE

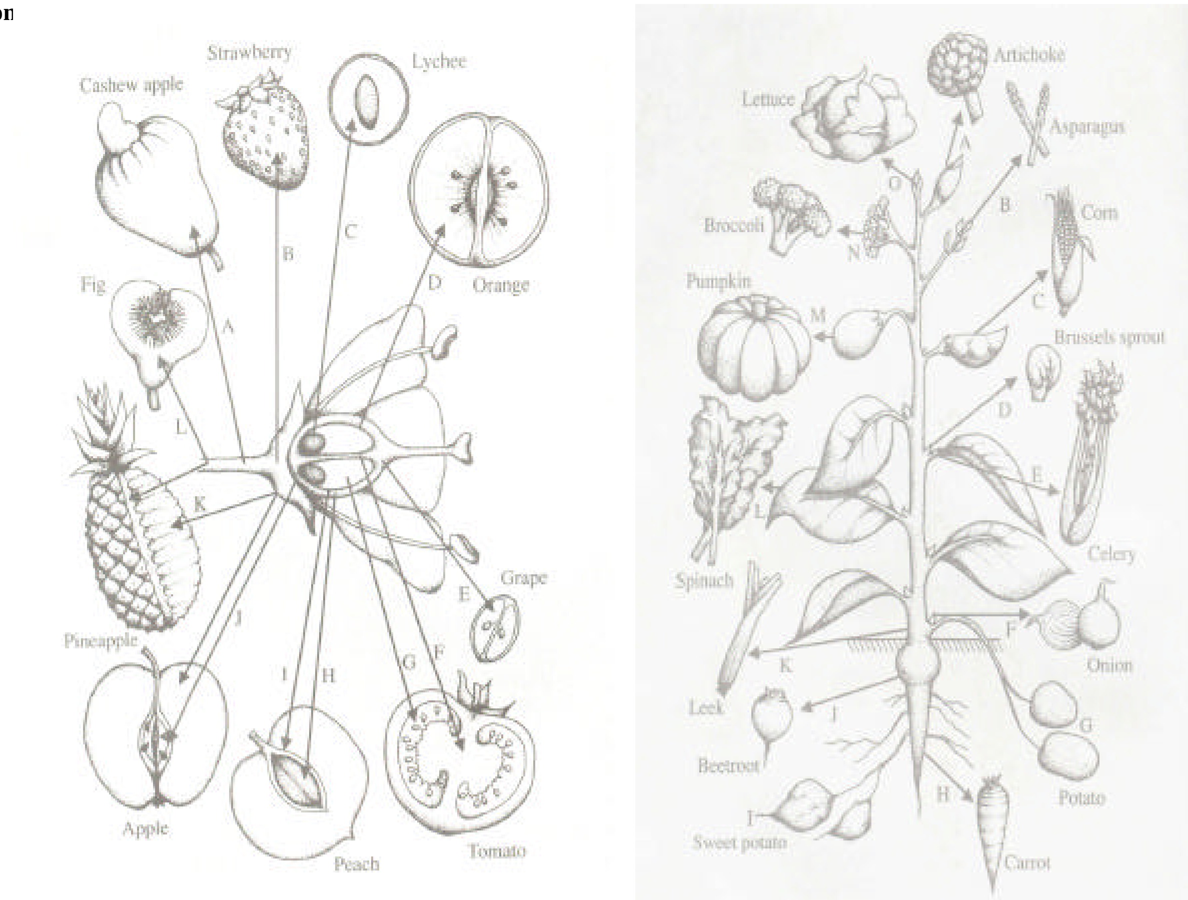
Food provides nourishment to our body. Food is absorbed by the body and used as an energy source. It is also used for growth and regulation. Further it also gives protection against diseases. In short, food is the raw material from which our bodies are made. Right kinds of food in right proportions can ensure good health, which may be evident in our appearance, efficiency and overall well being.

The foods which we use daily include rice, wheat, pulses, vegetables, fruits, milk, eggs, meat, fish, sugar, oils, etc. These foods are made up of a number of chemical substances called nutrients. According to their chemical structure, these nutrients can be classified as carbohydrates, proteins, fats, vitamins, and minerals. Water and fibre are also essential component of foods. Carbohydrates comprise sugars, starches, fibre, and related materials and mainly provide energy to our body. Proteins are nitrogenous compounds and form major component of tissue in our body. Fats provide energy and fatty acids to our body. Vitamins and minerals are required for metabolism and play a protective role in our body. In short, nutrients are essential for each and every voluntary or involuntary activity of the body and must be supplied by the diet.

9.3 FOOD STRUCTURE, TEXTURE, FLAVOUR, COLOUR, KEEPING QUALITY

9.3.1 Food Structure

Fruits and vegetables are important parts of our diet, they play a protective role as they supply the essential components to our body. Fruits and vegetables are living organisms and diverse in structure, in composition and in general physiology.



(a) **(b)**

Fig.9.1: a) Derivation of some fruits from plant tissue. The letters indicate the tissues that comprise a significant portion of the fruit illustrated as follows: A) pedical, cashew apple; B) receptacle, strawberry; C) aril, lychee; D) endodermal intralocular tissue, orange; E) pericarp, grape; F) septum, tomato; G) placental intralocular tissue, tomato; H) mesocarp, peach; I) endocarp, peach; J) carpels, apple; K) accessory tissue, apple and pineapple; L) peduncle, pineapple and fig. b) Derivation of some vegetables from plant tissue. The letters indicate the principal origins of representative vegetables as follows: A) flower bud, artichoke; B) stem sprout, asparagus; C) seeds, corn; D) axillary bud, brussels sprout; E) petiole, celery; F) bulb (underground bud, onion; G) stem tuber, potato; H) swollen root tuber, sweet potato; J) swollen hypocotyls, beetroot; K) swollen leaf base, leek; L) leaf blade, spinach; M) fruit, pumpkin; N) swollen inflorescence, broccoli; O) main bud, lettuce.

In general, however, the ovule develops into seeds and the ovary into fruit. Normally three layers are differentiated in the ovary wall or pericarp, these being the outer exocarp or skin, the mesocarp, which may be fleshy, and the inner endocarp. The structural features of fruits and vegetables on the basis of their derivation are shown in Fig 2.1a & 2.1b.

9.3.2 Food Texture

Food texture is a combination of sensations derived from the lips, tongue, walls of the mouth, teeth, and even the ears and touch by hand. The texture of fruits and vegetables depends on the turgor of the living cells as well as on the occurrence of supporting tissues and the cohesiveness of the cells.

9.3.3 Food Flavour

Flavour is the subtle and complex perception that combines taste, smell, heat and cold, and texture. The substances mainly responsible for the flavours of foods are volatile compounds. These may be aliphatic esters, aldehydes or ketones which are present in fruit and other natural foods in very low concentration. Orange, lemon and grapefruit peels contain a number of flavanone glycosides. Terpenoids are major components of citrus oils and contribute to the flavour of citrus fruits. Certain volatile sulphur containing compounds possess powerful and distinctive odours which contribute to both the pleasant and unpleasant aroma of many foods e.g. onion, garlic, cauliflower, broccoli etc.

9.3.4 Food Colour

The characteristic colour of raw food is due to the pigments naturally present in it. The natural colours (pigments) in vegetables and fruits can be classified on the basis of chemical structure as carotenoids (yellow -orange), chlorophylls (green), flavonoids and anthocyanins (red, blue, and purple) and anthoxanthins (cream yellow). Animal foods contain myoglobin and hemoglobin.

Chlorophylls are present in plants and vegetables especially leafy vegetables such as cabbage and lettuce etc.

Carotenoids are present in many vegetables and fruits such as carrot, pumpkin, mango, orange etc. Some of the carotenoids have vitamin A activity.

Anthocyanins - These occur in many fruits and vegetables e.g. coloured grapes, red cabbage, cherries, strawberries, plums, apple and in many flowers.

Flavonoids - Flavones and anthoxanthins are responsible for the yellow-white or creamy white colour of potato and cauliflower. Flavonoids are usually more stable to heat and oxidation than the anthocyanins.

Anthoxanthins – present in some fruits and vegetables.

Poly-Phenols - These are colourless or yellow substances which turn brown when fruits and vegetables containing them, e.g. brinjal, bottle gourd, apple, are cut and exposed to air. *Xanthones* are a group of red and yellow pigments. One well-known member is mangiferin, which occur as a glucoside in mangoes.

Betalains – betalains are a group of red and yellow pigments found in red beet and to some extent in cactus fruits, pokeberries and a number of flowers

9.3.5 Keeping Quality

The quality of fresh fruit and vegetables is related to their appearance, colour, uniformity, taste, flavour, texture, aroma, nutritive value, chemical composition, defective marks on the skin, chemical residue, additives and any other parameter the consumer chooses to be acceptable on the basis of their experience and education. Harvesting of fruits and vegetables disturbs the normal life process. As the fruits and vegetables continue to respire after harvesting, they start losing their vitality, turgidity, colour, appearance and food value and thus overall quality of food during storage at room temperature. Maturity level at the time of harvesting, harvesting practices of fruits and vegetables, handling practices, moisture content of foods, storage temperature, humidity and other storage conditions (light, oxygen, etc.) affects the keeping quality of the food. Keeping quality or storage stability (to preserve the overall quality during storage) is measured under storage and handling conditions that are set up to stimulate or somewhat exceed the conditions the product is expected to encounter in normal distribution and use.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Describe the significance of food for us?

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2. What do you understand by food flavours? Explain in brief.

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3. List the colour pigments present in fruits and vegetables.

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9.4 DEGRADATION OF NUTRIENTS, COLOUR PIGMENTS AND MICROORGANISMS DURING THERMAL PROCESSING AND STORAGE

9.4.1 Effect of Thermal Processing on Nutrients, Colour Pigments and Microorganisms

Almost all foods except fruits and some of the vegetables (used for salads) are subject to some type of heat processing to make them palatable and digestible. Thermal processing has both beneficial and adverse affects i.e. loss of nutrients. The loss of nutrients depends upon the processing temperature, duration of heat treatment and type of nutrients.

Blanching is a process in which dipping of fruits and vegetables in boiling water or exposing to steam for a few minutes stops all enzymatic and biological activities prior to processing. Losses of nutrients due to blanching occur directly from leaching of water soluble vitamins into water used for processing. In blanched vegetables such as asparagus, green beans, peas, spinach, the retention of ascorbic acid (67-95%), niacin (83-94%), riboflavin (88-90%) and thiamine (85-92%) is variable.

Pasteurization destroys pathogenic microorganisms associated with food and increases the shelf life by decreasing the microbial population and inactivates some enzymes. Pasteurization affects the vitamin content to a greater extent than other nutrients, e.g. vitamin C and riboflavin are most sensitive whereas vitamin E and K are slightly affected. Thiamine undergoes 3-20% destruction and riboflavin reduces to about 5%. Niacin content increases by about 10%, probably because of the liberation of protein bound nicotinic acid. Ascorbic acid being most sensitive undergoes oxidation. About 8% loss of vitamin C takes place during pasteurization.

Canning

Heating of canned fruits, juices, soups, vegetables, meat, and meat products etc. to destroy food spoilage microorganisms and enzymes result in some undesirable changes in the nutritive value of food. During canning, denaturation of proteins may occur. Heat, metallic tins and light accelerate oxidative rancidity of fats/ oils. The rate of oxidation of fat is doubled for each degree increase in the temperature. Sugars and starches are degraded by prolonged heating at high temperature. Browning reactions takes place in sugars on heating. Canning of vegetables causes losses in nutrients such as vitamin C (33-90%), thiamine (16-83%), riboflavin (25-67%), niacin (0-75%), folic acid (35-84%) and vitamin A (0-84%).

Ionizing Radiations

Effects of irradiation on the nutritional quality of foods vary with doses. Higher doses result in more destruction of nutrients than lower doses. Irradiations produce molecular changes in starch, converting it into sugars. Lipids are very sensitive to radiations. Auto-oxidation of lipids increases peroxide value i.e. the number of peroxides increases leading to off-flavours. Losses of amino acids also occur. During irradiation most of thiamine is found to be lost whereas riboflavin is heat stable and retained upto 91%. Niacin and folic acid are extremely radio-resistant and are fully retained. Vitamin K is sensitive to radiation and is destroyed in significant quantity during irradiation.

Colour Pigments

Vegetables and fruits contribute a variety of colours to the diet. The plant pigments chlorophyll (green leafy vegetables), carotenoids (yellow-orange carrots), flavonoids (white potatoes) and anthocyanins (red beetroot) are present singly or in combination in plant foods. These may be affected by the method of food processing. The soluble pigment such as anthocyanins may leach in the cooking water and changes may occur due to the effect of heat and pH (Table 9.1).

Table 9.1: Effect of heating on colour pigments of plant foods

S. No.	Food source	Name of pigments	Colour	Soluble in	Effect of prolonged heating	In presence of	
						Acid	Alkali
1.	Rice Potato	Flavones Flavanols	White or yellowish red	Water	May darken	White	Yellow
2.	Beetroot	Anthocyanin	Red	Water	Little	Bright red	Reddish purple
3.	Leafy vegetables	Chlorophyll	Green	Fat	Olive green	Olive green	Intense green
4.	Carrot Mango Tomato	Carotene Xanthophyll Lycopene	Yellow - orange	Fat	May darken	No change	No change

9.4.2 Effect of Storage on Nutrients, Colour and Microorganisms

The quality of food deteriorates during storage due to action of microorganisms on them if not stored properly. Deterioration is usually noticed by the presence of rancid odour of fats (caused by oxidation of fats), fermented odour of fruit or fruit juices due to yeast growth, or appearance of mould growth on bread, roti, etc. Hence, proper storage of food and food products is very important to avoid the quantitative and qualitative losses.

Fresh fruits and vegetables continue to respire after they are harvested. Harvesting disturbs the normal life processes, and vegetables start losing their vitality, turgidity and food value. The harvested vegetables continue to respire during transport and storage. This involves the use of oxygen, the metabolism of cell food materials and the release of carbon dioxide, water and energy. Most of the energy is released in the form of heat.

Most of the fruits such as mango, banana, citrus, guava, grapes, papaya, etc. are prone to injuries which become avenues for fungi especially moulds which deteriorate the fruits. The fruit packaging material is infested with organisms, which also act as source of infection. Due to unhygienic practices, fruits are subjected to various diseases causing huge losses. The most common type of spoilage in fruits and vegetables are bacterial soft rot, gray mould rot, blue mould rot, black mould rot, pink mould rot, etc. Fungal spoilage of vegetables often results in water soaked mushy areas, while fungal rots of fleshy fruits like apple and peaches mostly show brown or cream coloured areas in which moulds grow in the tissue below the skin. Whereas bacterial soft rot is commonly spread among the vegetables which are not very acid and among the fruits which are not highly acid.

Sometimes normal changes occur in raw fruit juices at room temperature such as alcoholic fermentation (conversion of sugars to acid, alcohol and gases) by yeasts, which further cause an oxidation of alcohol and fruit acids yeasts and moulds growing on the surface when it is exposed to air. Mostly at temperatures above 32.2^{0}C to 35^{0}C lactobacilli would be likely to grow and form lactic acid and some volatile acids.

Vitamin C and thiamine may be lost if canned foods are stored at ambient temperature. At room temperature, there is discolouration of pigments present in vegetables such as anthocyanins, flavanols and flavones very rapidly because of the activity of enzymes. Roots and tubers can be stored in cool ventilated place to avoid sprouting. Storage temperature should be maintained between 3 and 10^{0}C. Green leafy vegetables after harvest start losing resulting in loss of moisture. These vegetables can be stored at low temperature in clean and dry plastic bags to prevent loss of moisture.

The most common deteriorative changes taking place in milk at room temperature are souring, decomposition of protein, rancidity or bitter taste, off flavour, colour changes etc.

Deteriorative changes in meat can take place in aerobic conditions, anaerobic conditions and also by bacteria, yeasts or moulds. The changes, which take place under anaerobic conditions, are changes in colour, oxidation of unsaturated fats, undesirable flavour, off odour, of taste, etc.

Fish gets spoiled easily because of the rapid autolysis by the fish enzymes. The fat in pork and poultry are more easily oxidized than others.

Eggs are more spoiled by bacteria than moulds. If not properly stored there is a loss of CO_2 gas through the egg shell, loss of moisture and increased air space, loss of moisture from white to yellow, loss of normal firmness of egg white, etc.

Foods when properly stored retain their freshness longer; have better nutritive value and acceptability. Therefore, for better storage and long shelf life, all food and food products should be stored in a proper place according to their requirement.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Mention the nutrients, which are sensitive to temperature and light.

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2. How temperature affects the colour pigments? Explain.

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3. Why do the quality of harvested fruits and vegetables deteriorate?

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4. Why do the fruits and vegetables spoil at room temperature?

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9.5 PERMITTED COLOURS

Food Colours

The acceptance of food depends to a large extent upon its attractive colour. The characteristic colour of raw food is due to the pigments naturally present in it. Sometimes, artificial colour is added during the preparation and processing of foods to make them more attractive.

List of Permissible Harmless Food Colours

i) Natural colouring matter that may be used:

According to Fruit Product Order, India (1955), the natural colouring matters, whether isolated from a natural source or synthesized, are permitted to be added to any food product. Some of these are carmine, carotene and carotenoids, chlorophyll, caramel, annatto, ratanjot, and saffron.

ii) Coal tar dyes which may be used:

No coal tar dyes or a mixture thereof except the following shall be used in fruit products:

Colour	Common name	Colour index (1956)	Chemical class
i. Red	Ponceau 4R Carmosine Fast Red E Amaranth Erythrosine	16255 14720 16045 16185 45430	Azo Azo Azo Azo Xanthene
ii. Yellow	Tartrazine Sunset Yellow FCF	19140 15985	Pyrazolone Azo
iii. Blue	Indigo Carmine Brilliant Blue FOF	73015 42090	Indigoid Triphenyl-methane
iv. Green	Green S Fast Green FOF	44090 42033	Triphenyl-methane Triphenyl-Methane

Dyes when used in fruit products shall be pure and free from all harmful impurities. The maximum limit of any permitted coal tar colours or mixture of permitted coal tar colours which may be added to any fruit products, shall not exceed 0.20 g per kg of the final products for consumption.

As per the 'Code of US Federal Regulations (1979); and Prevention of Food Adulteration Act (India), Acid Magenta II, Blue VRS, Brilliant Black, Red FB, Red 6B colours have been prohibited for use in the food products.

9.6 HEALTH FOOD, GREEN/ ORGANIC FOOD, TRADITIONAL FOODS, DESIGNER FOODS

9.6.1 Health Food

Health foods are those, which are nutritious, prevent diseases and maintain health. Health foods are also known as 'designer foods'. Such foods must possess characteristics like modified composition, limit the presence of certain potentially harmful components and possibility of including certain desirable ingredients either naturally or by addition. These include vegetable foods, whole grain cereals, food processed without chemical additives, foods grown on organic compost, 'magic' foods (honey, molasses, yoghurt, etc.), and so on.

9.6.2 Organic Foods

Organic foods refer to the foods (either plant or animal foods) that are grown organically. These are grown on soils enriched with compost and manure and without the use of chemical fertilizers, insecticides or pesticides. Organic foods are the need of the hour because these foods offer protection of future generations, prevent soil degradation and erosion, protect water and aquatic life, save energy, protect farmers and farm women, help small farmers, support a true and sustainable economy, promote biodiversity, produce better, tasty, pure and nutritious foods.

9.6.3 Traditional Foods

Traditional foods are different types of food preparations with varying shelf life. These foods had been invented to overcome the monotony in the diet of the people, modified and repetitively processed by human communities. Their composition and preparation were based on the Pak Sastra i.e. Science of cooking. Traditional food processing began when man ceased to be a food hunter. To start with, it was confined to primary processing of food grains. Gradually, primary processing spread to other foods, gathering variety, variegation and velocity. In regions of primitive agriculture, food manufacture and management, man is still engaged in simple food processing practices, passed down through generations of tradition.

Indian traditional foods based on cereals, legumes and fats or oil - both sweets and savories, are innumerable in number, with characteristic features reflecting the diverse socio-cultural environments in different parts of the country. In our country; a nation steeped in culture and tradition dating beyond 5000 BC, these heritage foods for which preparative guidelines passed on from generation to generation are still made by skilled mothers and grandmothers, though many of these products have attained commercial importance during last 20 – 30 years.

Amongst various traditional foods, cereals and pulses based products still occupy an important place in the diets of our people. Historically, legumes are the natural protein supplements to cereals in the Indian diets. ‘Khichari’ one of the traditional products prepared from rice and pulse to prove a good quality diet, was in practice long before nutritionists and food scientists understood the nutritional importance of mixing grains.

The important traditional foods which are still popular among Indian population can be broadly categorized as: processed grain products, dehydrated foods, pickles/chutneys/sauce/relishes, ground spice/spice mixture, fried food products, confections and sweet dishes, and dairy products. Some popular traditional foods prepared and served at homes, restaurants and public eating places (bus stops, railway stations) with subtle differences in blends and flavours but essentially Indian are listed in Table 2.2.

Table 2.2: Some characteristic traditional foods of India

Major raw material	Products
Cereals/legumes	Papads, Wadian, Vermicelli, Soji, fried snacks.
Milk	Malai, Khoa, Chhana, Paneer, Curd, Butter milk.
Milk and sugar/jaggery	Peda, Burfi, Rasagolla, Jamun, Sandesh, Kheer, Halwa
Gram flour, sugar/jaggery	Mysore Pak, jilebi, Laddu and Chikki
Fruits and vegetables	Pickles chutneys, Murabbas, Patha, candied fruits, Aamchur, Fruit leather, dried fruits, dehydrated vegetables and pickled vegetables.
Spices and condiment	Spice powder, Sambar and Rasam powders and Garam masala
Miscellaneous	Neera, toddy, arrack, feni, vinegar, jaggery, khandasari, Sugar, and honey.

9.6.4 Designer Foods

Designer foods are foods that naturally contain or are enriched with certain specific concentration and proportion of nutrients/ substances that are important to health and prevent certain diseases such as phytochemicals (prevent cancer). The term was first coined in 1989 by Dr. Herbert Pierson, The National Cancer Institute (U.S.). The designer foods are also called as medical foods, fortified foods, nutritional foods, neutraceutical foods, functional foods, indulgence foods, slow foods, premium foods, therapeutic foods and healthier foods. Such foods are most commonly conceived as health foods that have therapeutic or prophylactic characteristics. The term "designer food" is subjected to change based on nutritional labelling regulations, new developments, consumer perceptions and expectations. Therefore it can be said that designer food is an evolving concept meant for reducing or delaying the risk of diseases.

9.7 PACKAGING FOR SAFETY AND QUALITY

Packaging of fruits and vegetables is undertaken primarily to assemble the produce in convenient units for marketing and distribution. The package must be capable of (i) protecting the produce from the hazards of transport, (ii) preventing microbial and insect damage and (iii) minimizing physiological and biochemical changes.

The important consideration in selecting the packaging material are (i) the product itself, (ii) the system of production, (iii) the systems of storage, (iv) the systems of handling, (v) the system of transport, (vi) the systems of merchandising, (vii) the consumer attitude, (viii) requirement of recycling/ reuse/ disposal, etc.

The traditional types of food packaging are boxes, cartons, metal cans, glass bottles and jars whereas the new innovations in packaging are aseptic packaging, PET containers, microwaveable containers, controlled/ modified atmosphere packaging etc.

a) Packaging for fresh fruit and vegetables

Fresh produce contains 80-90 per cent of moisture or even more and equilibrate humidity as high as 98%. Under normal atmospheric conditions, they will dry rapidly (transpiration). This causes wilting and shriveling due to shrinkage of cells. The existing postharvest loss of fruits and vegetables could be considerably reduced by adopting improved packaging, handling and efficient system of transport. The fresh fruits and vegetables during postharvest phase continue all vital processes. The respiratory heat liberated by fruits and vegetables must be taken out from the pack in order to extend their storage life. For this purpose film thickness, ventilation in the packs plays a very important role.

Modified Atmosphere packaging (MAP)

Plastics play a great role in creation of modified atmospheric (MA) condition around the commodities when the fresh fruits and vegetables are packed in plastic film bags. MA condition was reported to reduce bitter pit reduction and better retention of vitamin C in apples. The acute problem of ripening of Suvernarekha mangoes during transit was solved by adopting the MAP technology. However, proper temperature management and postharvest handling practices are required for storing these mangoes for longer duration (30-40 days). Similarly by adopting MAP technology, Mallika and Amrapali varieties of mango fruit could be kept up to 25 days at low temperature. The technology was also successfully applied to enhance the storage life with better quality attributes in many other fruits and vegetables viz. guava, cauliflower etc.

Prepackaging is generally defined as packaging the produce in consumer size units either at producing center/ farm before transit or at terminal markets. Prepackaging protects the produce against the damage and excessive moisture loss, reduce transportation cost by eliminating unwanted and inedible portion of fruits and vegetables, reduces the shopping time of the consumer as the produce is graded before packaging.

b) Packaging for processed products

The packaging materials used for various food products are metal cans, glass bottles/ jars, rigid/ flexible plastic packaging materials etc. Products like fruit jams, jellies, pickles are packed in wide mouthed glass jars. Products like fruit, squashes, syrups, RTS beverages, carbonated beverages etc. are packed in glass bottles.

Packaging for dried or dehydrated products

Dehydrated vegetables absorb moisture; they require a moisture resistant pack. Smaller sized packs of dehydrated vegetables are packed in heat sealable laminates consisting of PE, aluminium foil and paper. Powdered dehydrated products like fruits juice powders, soups, and custard powders require protection against ingress of moisture, oxygen and loss of volatile flavours and colour. They are usually packed in heat sealable laminates containing a layer of Aluminium foil. Cabinet dried, sulphured or sulphited mango pieces could be stored for 6 months in 400 gauge PE pouches for making Amchur.

Packaging for accelerated freeze dried (AFD) foods

The light, porous and brittle nature of AFD foods renders them susceptible to mechanical damage that affects the reconstitution characteristics. So, AFD foods must be protected against physical breakdown, moisture and oxygen absorption. *Aluminium foil laminates* are the best suited. Glue and cartons with foil laminates secured to the walls by spot gluing are suitable for over-all protection of AFD foods.

Bulk packaging of base products like fruits pulp and other intermediate products in plastics laminated pouches is practiced widely amongst manufacturers and processors. A variety of the finished products of fruits and vegetables viz. tomato products, fruit syrups, carbonated drinks and dehydrated fruits and vegetables are packed in plastic containers/ pouches.

Aseptic packaging

Aseptic packaging refers to a technique in which the product and the containers are sterilized separately and packed in a completely aseptic environment till it comes out of the system. Aseptically packaged juices and puree can be distributed in parts where refrigeration is not common. In aseptically processed 'bag-in-box' packed guava and papaya puree, no loss of vitamin C and flavour was observed but loss in colour took place.

Vacuum packaging

Vacuum packaging is used when the foodstuffs is susceptible to deterioration in the presence of oxygen. The air from the container is removed after filling the container and before sealing. This packaging increases the shelf life and quality of the packed material.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. List the permitted colours? What is maximum limit of colour in fruit product?

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2. Briefly describe the health foods.

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9.8 LET US SUM UP

Food is essential to provide nourishment to our body to perform various functions. The appearance, colour, flavour, texture, and all other food qualities affect acceptance of the fresh and processed products. As respiration continues after harvesting, fruits and vegetables lose their vitality, turgidity, colour, appearance and food value, and thus overall quality at room temperature. Improper handling and transport increase the qualitative and quantitative losses. Heating brings several changes in the soluble colour pigment of fruits and vegetables. In order to maintain the wholesomeness of the fresh and processed products, these should be handled properly, transport carefully, stored under appropriate conditions and processed following the standard practices.

The packaging of produce and products is important to protect the produce from the hazards of transport, prevent microbial and insect damages, minimize physiological and biochemical changes and for longer shelf life.

9.9 KEY WORDS

Blanching : dipping of fruits or vegetables in boiling water or exposing these to steam for a few minutes to kill enzymatic and biological activity prior to processing.

Canning : process of sealing of foodstuffs hermetically (air tight) in containers and sterilizing them by heat for long storage.

Degradation : loss of quality.

Denaturation : structural change in proteins due to effect of heat, light, change in pH etc.

Deterioration : includes adverse changes in organoleptic quality, nutritional value, food safety, asthetic appeal, colour, texture and flavour.

Growth : increase in the physical size.

Oxidation : change in a molecule, which involves gain of oxygen, removal of hydrogen or loss of electron.

Quality of fruits and Vegetables : often referring to particular flavour characteristics, appearance, size or levels of a particular type of damage.

Turgor : pressure of cell contents on the partially elastic wall of a cell, tending to produce rigidity. One of the best known forces affecting cell volume is osmosis.

9.10 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Any eatable items provide nutrients is food.

   Food contain different nutrients namely carbohydrates, proteins, fats, vitamins, and minerals to perform various functions. See sub-sec. 9.1 and 9.2.

2. Volatile compounds are responsible for food flavour.

   Flavour compounds present in different fruits and vegetables. See sub-sec. 9.3.3

3. Different colour pigments with examples. See sub-sec.9.3.4.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Blanching causes loss of water soluble vitamins due to leaching.

   Pasteurization (<100^0 C) destroys some of vitamin C and Riboflavin.

   High temp. during canning destroys water soluble vitamins significantly.

   Effect of canning on protein and fat. See Sub-sec. 9.4.1.

2. Effect of heating on colour pigments of plant foods. See Sub-sec. 9.4.1.

3. Respiration continues after harvesting.

   Metabolic heat of fruits and vegetables, improper handling and storage conditions causes deterioration in quality. See sub-sec.9.4.2.

4. Room temperature is favourable for growth of microorganisms.

   Enzymatic activities in fresh produce are high at room temperature. See Sub-sec.9.4.2.

Check Your Progress Exercise 3

Your answer should include the following points:

1. List of permitted colours.
   Limit of colours in fruit product. See sub-sec. 9.5.

2. Definition and characteristic of health foods. See sub-sec. 9.7.1 & 9.7.4.

9.11 SOME USEFUL BOOKS

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UNIT 10 LOSS OF FOOD VALUE IN FRESH PRODUCE AND PROCESSED PRODUCTS

Structure

10.0 OBJECTIVES

After reading this unit, you should be able to:

- describe the protection and preservation techniques;
- explain biochemical changes after harvesting and slaughter; and
- discuss the handling, transport and safe storage of fruits and vegetables.

10.1 INTRODUCTION

Fruits and vegetables are highly perishable commodities. These are affected by a number of factors leading to post harvest spoilage and hence, post harvest losses are the major source of food loss. Besides, packaging, transportation, and marketing of these perishables also contribute to post harvest losses. These are passed through a long channel before their use, which may lead to a number of undesirable physico-chemical changes in their composition. The losses may take place further, if the produce is not processed following the scientific methodology. In order to reduce the losses and maintain the quality to a maximum extent, effective post harvest management of fruits and vegetables during handling, transportation, marketing, and storage of fresh and processed products is of great importance.

10.2 ASSESSMENT OF LOSS

Fruits and vegetables respire even after harvesting and undergo biochemical changes. Their condition and marketable life are affected by temperature, humidity, composition of the atmosphere which surrounds them, level of damage that has been inflicted on them before, during and after harvest, and the type and degree of infection with microorganisms, insects etc. Fruits and vegetables will deteriorate during storage through loss of moisture, loss of nutrients, physical loss through pest and disease attack, loss in quality from physiological disorders, fibre development, greening (potatoes), shoot growth, seed germination etc.

Various loss assessment methods have been used in practice for perishable commodities. In a study of apples arriving at a central market in Mexico over a period of one year, various measurements were made using European Community (EC) Standards (Table 10.1).

Table 10.1: Quality standards and losses of apples at wholesale market level in Mexico

Quality rating	Reasons for being unmarketable	Percentage
Extra		0.2
1		11.0
2		29.6
3		25.7
Below 3		15.5
Unmarketable		18.0
	Physiological (dehydration, over-maturity, physiological disorders)	9.0
	Fungal diseases (Penicillium, Gloeosporium, Phytophthora)	10.0
	Insect infestation	2.1
	Bitterpit	1.4
	Freezing injury	0.2
	Mechanical damage	6.8

Source: Noon R.A. (1979). Report on an assignment as Plant Pathologist to CONAFRUTA, Mexico City, March 1977-September 1979. Tropical products Institute Report R923, 34 pp.

The factors in the life cycle of fresh fruits and vegetables, which can influence their post-harvest losses, are crop production factors (temperature, nutritional status, light, day length, chemical treatments, infections or infestations etc.), maturity level at harvesting, method of (manual or mechanical) harvesting, removing crops from the field, treatments (pesticides, heat, sprout suppressants, curing), storage and transport conditions, packaging, type of transport, type of store, temperature (pre-cooling, store temperature), humidity, and atmospheric gases.

Losses occur at different times during the production and post harvest cycle of crops, and have a variety of causes. If it is clear that the losses are due to infections caused by microorganisms the control measures will depend on the type of microorganism, the time of infection, the reason for the success of infection and permissible control measures. It follows that effective and sustainable control of post harvest losses should be an integrated approach taking into account health, economics and practicality of the situation. It is important to know the time in marketing chain when losses occur. Losses are usually higher when the crop enters the marketing chain (particularly during wholesale marketing) than in crops consumed by the producer.

10.3 FACTORS CAUSING SPOILAGE: PHYSICAL, PHYSIOLOGICAL, THERMAL, MICROBIAL, CHEMICAL, INSECTS, PESTS, DISEASES

Factors causing spoilage often do not operate in isolation. At one time, many forms of deterioration may take place, depending on the type of food and the environmental conditions that its exposed to.

Physical Factors

Storage conditions like temperature, oxygen, light, duration of storage etc are the important factors that influence the type of microbial growth and spoilage.

The rate of a chemical reaction doubles itself for every 10^0 C rise in temperature. Excessive heat brings about protein denaturation and destruction of vitamins. Several fruits and vegetables deteriorate even at refrigeration temperature (4^0 C) resulting in disclouration, changes in texture etc. Freezing may also cause deterioration of liquid foods e.g. separation of fat particles from a food emulsion.

Atmospheric oxygen brings about undesirable changes in foods such as discolouration, flavour changes and loss of vitamin A and C. Light destroys riboflavin, vitamin A and C and also many food colours. All the other food deterioration factors are time-dependent. The longer the storage time, greater the deterioration of food.

Physiological Factors

Rate at which the stored product respires is a major factor in determining the pace of physiological ageing. Deterioration in fruits and vegetables occurs mainly through the process of physiological ageing and water loss.

The characteristics of a food influence the type of microorganisms that can grow in it and thus determine the changes in its appearance, flavour and other qualities. Proteins are degraded by proteolytic organisms. Fats are digested by relatively few microorganisms, mainly moulds. Fats become rancid due to hydrolytic decomposition to mal-odourous fatty acids. Carbohydrates are affected by carbohydrates fermenting microorganisms; particularly yeasts and moulds.

Moisture is required both for chemical reactions and microbial growth. Foods with a high percentage of moisture deteriorate fast. Variation in surface moisture due to change in relative humidity can lead to lumping and caking, surface defects, crystallization and stickiness in foods. Condensation of even small amounts of moisture can result in multiplication of bacteria.

Acidity- Due to low pH, most of fruits are mainly spoiled by yeasts and moulds. Nonacid foods (vegetables, meat, fish, milk) are particularly subject to bacterial spoilage, but also support growth of moulds under favourable conditions.

Thermal Factors

Inappropriate temperature during food processing and storage are one of the main causes of food deterioration. At high processing temperature proteins get denatured and browning takes place (Maillard reaction). Water soluble vitamins particularly vitamin C, thiamine and riboflavin are heat sensitive and destroyed at high temperatures. Oxidative rancidity is accelerated by heat, metallic tins and light. The rate of oxidation of fat is doubled for each degree increase in temperature. Sugars and starches are degraded by prolonged heating at high temperature.

Microbial Factors

Bacteria, yeasts and moulds often cause food spoilage after harvesting, during handling, processing and storage. They attack all the food components – sugar, starche, cellulose, fat and protein. Depending on the food and the microorganisms, the action on food could be to produce acids, making the food sour, or produce alcohol. Some microorganisms produce gases, making the food foamy; still others produce unwanted pigments or toxins.

Chemical Factors

Pesticides can leave residues on plant produce much more than safe limits and make them unfit for consumption. Poisonous chemicals may enter foods from utensils, e.g., from cadmium plated ware or cheap enamelled ware containing antimony. Lead and arsenic residues from fruit sprays may be on fruit surface, but usually in harmless amounts, especially after washing. Indiscriminate use of all plastic packaging material like polyvinyl and polyethylene material can be a health hazard, e.g., it may lead to the reaction of acid and oil of pickles with plastic packaging as observed in some cases.

Insects, Pests, Diseases

Insects, worms, bugs and fruit flies may damage foodstuffs such as grains, fruits and vegetables and render them unfit for consumption. Apart from losses due to food eaten, insects cause greater damage due to bruises and cuts they make in foods exposing them to microbial attack resulting in total decay. Pests such as rodents introduce high degree of filth in form of excreta, bodily secretions and spoilage microorganisms. For example, rats can transfer the bacteria S*almonella* to the food, may cause salmonellosis.

Several types of pathogenic fungi are able to initiate an infection on the surface of floral parts and on, developing fruits. Many fungi that cause considerable wastage of produce are unable to penetrate intact skin of the produce, but readily invade broken skin. In addition, the cut stem is a frequent point of entry for microorganisms, and stem-end rots are important forms of post harvest wastage of many fruits and vegetables.

Table 10.2: Major post harvest diseases of some fresh fruits and vegetables

Crop	Disease	Pathogens
Apple, pear	Lenticel rot Blue mold rot	*Phlyctaena vagabunda* *Penicillium expansum*
Banana	Crown rot Anthracnose	*Colletotrichum musae Arx, Fusarium roseum, Verticillium theobromae, Ceratocystis paradoxa* *Colletotrichum musae*
Citrus fruits	Stem end rot Green mould rot Blue mould rot Sour rot	*Phomopsis citri Faw, Diplodia natalensis, Alternaria citri* *Penicillium digitatum Sacc.* *Penicillium italicum Wehmer* *Geotrichum candidum*
Papaya, mango	Anthracnose	*Colletotrichum gloeosporiodes*
Pineapple	Black rot	*Ceratocystis paradoxa,*
Potato, leafy vegetable	Bacterial soft rot Dry rot	*Erwinia carotovora* *Fusarium species*
Leafy vegetables, carrot	Watery soft rot	*Sclerotinia sclerotiorum*

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand by spoilage?

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2. What are different factors that can deteriorate the quality of fresh and processed products? Explain in brief.

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3. How the pests can make the food unfit for consumption?

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10.4 POST-HARVEST/ SLAUGHTER – BIOCHEMICAL CHANGES

10.4.1 Post-Harvest Biochemical Changes

The perishable foods like fruits and vegetables continue to undergo chemical changes even after harvest. The changes of fruits after harvest are numerous. Some of the very important changes include changes in (i) rate of respiration, (ii) water content, (iii) carbohydrates and (iv) organic acids and pH.

i) A major metabolic process which takes place in harvested produce or in any living plant is respiration. Respiration rate per unit weight is highest for the immature fruits or vegetables and then steadily declines with the age.

ii) When fruit and vegetables are picked from the plants, water no longer flows into the foods although the loss continues. In dry atmosphere and at high temperatures, water loss is rapid. For e.g., apples rapidly cooled after delivery to the storage area have a much smaller water loss than those cooled slowly. During the ripening period of bananas, the water content in the pulp increases and in the peel decreases. Water loss in bananas (and probably in other fruits) is checked by waxy layer of the skin.

iii) Many changes occur in the carbohydrate fraction of fruits during ripening. This alters both taste and texture of the produce. The green fruits usually contain an abundance of starch, but are short on the soluble sugars that give ripe fruit its sweetness. On ripening, however, starches decrease and sugars increase in concentration.

One of the most obvious changes in fruit is the alteration in texture. The breakdown of polymeric carbohydrates, especially pectic substances and hemicelluloses, weakens cell walls and the cohesive forces binding cells together. In the initial stages, the texture becomes more palatable, but eventually the plant structures disintegrate. Protopectin is the insoluble parent form of pectic substances. During ripening and maturation, protopectin is gradually broken down to soluble pectin. The rate of degradation of pectic substances is directly correlated with the rate of softening of fruit. For e.g. pears are picked in the hard stage and held at low temperatures until required for ripening. On return to room temperature they rapidly ripen and soften due to increase in soluble pectin. Fruits like banana, peaches, plums and tomatoes also show loss of protopectin and rise in soluble pectins on ripening.

10.4.2 Post-Slaughter Biochemical Changes

There are a series of biochemical changes occurring after slaughter. When an animal dies, the skeletal muscles stiffen in rigor mortis and remain in this condition for a period after which they soften and become flexible again. The onset of rigor is quickened by high temperatures and delayed by low temperature. Rigor mortis is important in meat products since muscles cooked while still in rigor are much tougher than if it is allowed to soften before cooking. The stiffness, that develops when muscles pass into rigor, is the result of changes in the proteins. Living muscle fibres contain protein in a soft, pliable gel. During rigor this gel stiffens, but when rigor passes, the muscle again becomes soft and pliable. After the passing of rigor mortis, meat becomes progressively more tender, juicier, and more flavourful. The speed with which this ripening or aging occurs, depends on the time and temperature of keeping the carcass. Changes occur quite rapidly at room temperature but more slowly at refrigerator temperatures.

10.5 HANDLING AND TRANSPORT

Fruits and vegetables continue to respire even after harvesting. We cannot improve the quality of the harvested commodities but it can be retained till consumption if the rate of metabolic activities is reduced by adopting the appropriate post harvest handling operations (Fig. 10.1).

Pre-cooling

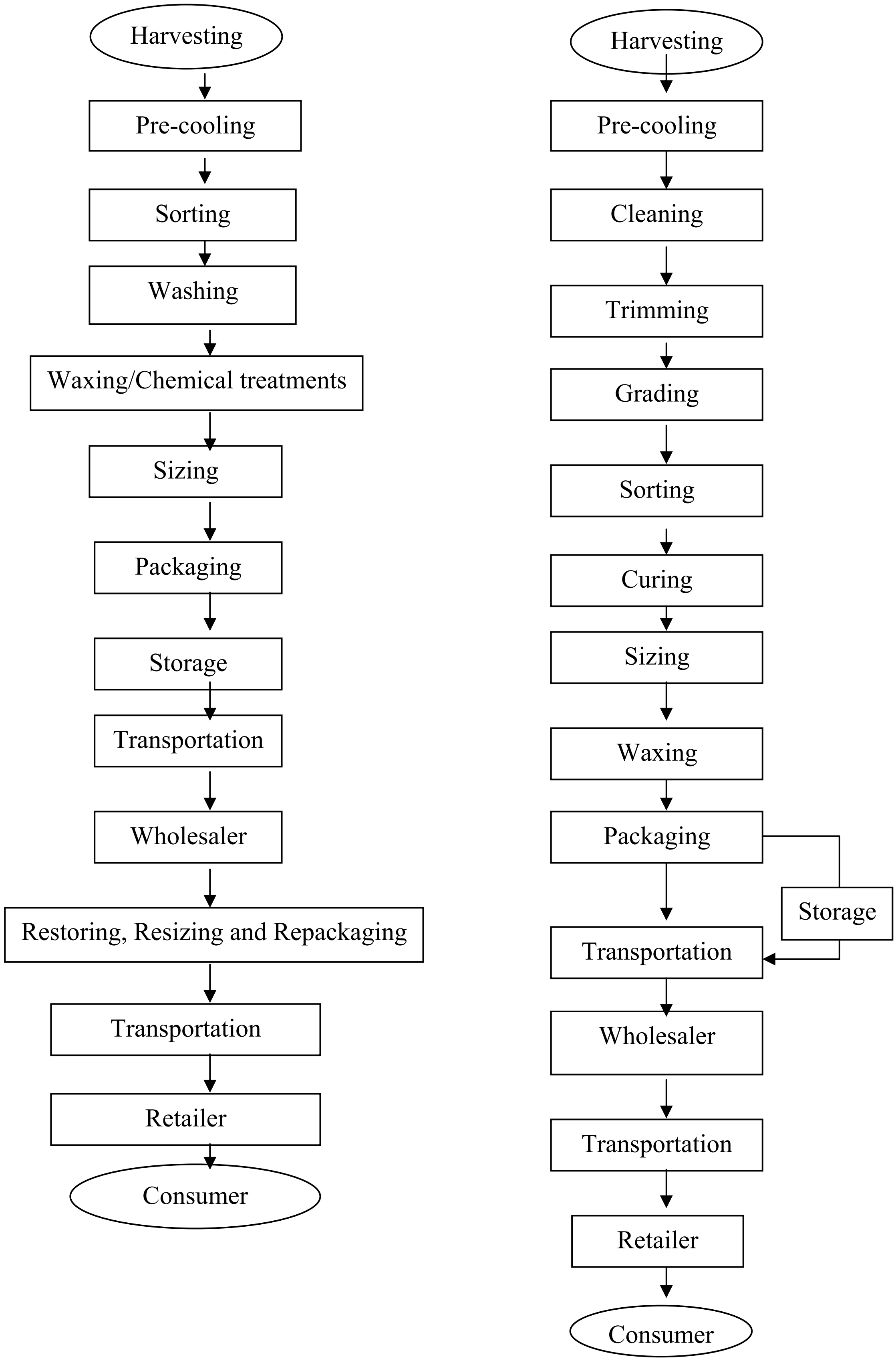
Pre-cooling (prompt cooling after harvest) is important for most of fruits and vegetables because they may deteriorate as much in 1 hour at 32^0C as they do in 1 day at 10^0C or in 1 week at 0^0C. In addition to removal of field heat from commodities, pre-cooling also reduces bruise damage from vibration during transit. Cooling requirement for a crop vary with the air temperature during harvesting, stage of maturity, and nature of crop. Different methods of cooling are given commodity-wise in Table 10.3.

Table 10.3: Commodity-wise cooling methods

Cooling method	Commodity
Room cooling	All fruits and vegetables.
Forced air cooling (pressure cooling)	Fruits and fruit type vegetables, tubers and cauliflower.
Hydro cooling	Stem, leafy vegetable, some fruits and fruit type vegetables.
Package icing	Roots, stem, some flower type vegetables, green onions and brussel sprouts.
Vaccum cooling	Some stem, leaf and flower type vegetables.
Transit cooling Mechanical refrigeration Top icing and channel icing	 All fruits and vegetables Some roots, stems, leafy vegetables

Washing, Cleaning and Trimming

Before fresh fruits and vegetables are marketed various amounts of cleaning are necessary which typically involves the removal of soil, dust, adhering debris, insects and spray residues. Chlorine in fresh water is often used as disinfectant to wash the commodity. Some fungicides like Diphenylamine (0.1-0.25%) or ethoxyquin (0.2-0.5%) may be used as post-harvest dip to control an important disorder of apple known as superficial scald. Many vegetables need trimming, cutting and removal of unsightly leaves or other vegetables parts.



(a) (b)

Figure 10.1: Post-harvest handling operations of a) fruits, and b) vegetables

Sorting, Grading and Sizing

Sorting is done by hand to remove the fruits, which are unsuitable to market or store due to damage by insects, diseases or mechanical injuries. The remainder crop products are separated into two or more grades on the basis of the surface colour, shape or visible defects. For example, in an apple packing house in India 3 grades viz. extra fancy, fancy and standard may be packed for marketing. After sorting and grading, sizing is done either by hand or machine. Sizing on the basis of fruit shape and size are most effective for spherical (oranges, tomato, certain apple cultivars) and elongated (delicious apples, European pears or of non-uniform shaped commodities, respectively. Grading-packing line machines with facilities of washing, waxing and drying in addition to sizing are now days available in the market.

Curing

Curing is an effective operation to reduce the water loss during storage from hardy vegetables viz. onion, garlic, and other root vegetables. The curing methods employed for root crops are entirely different than that from the bulbous crops (onion and garlic). The curing of root and tuber crops develops periderm over cut, broken or skinned surfaces for wound restoration. It helps in the healing of harvest injuries, reduces loss of water and prevents the infection by decay and attack by pathogens. Onion and garlic are cured to dry the necks and outer scales. For the curing of onion and garlic, the bulbs are left in the field after harvesting under shade for a few days until the green tops; outer skin and roots are fully dried.

Waxing

Waxing generally reduces the respiration and transpiration rates, but other chemicals such as fungicides, growth regulators, preservative can also be incorporated specially for reducing microbial spoilage, sprout inhibition etc. However, it should be remembered that waxing does not improve the quality of any inferior horticulture product but it can be a beneficial adjunct to good handling. Some of the commonly used waxes are paraffin wax, carnauba wax, bees wax, wood resins, shellac, etc.

The majority of quality contributing factors as affected by wax application includes reduction in the physiological loss in weight (PLW), delay in respiration rate, reduction in post-harvest spoilage and maintenance of improved quality of commodity intended for storage to increase the shelf life. The principal disadvantage of wax coating is the development of off flavour if not applied properly. Adverse flavour changes have been attributed to O_2 and CO_2 exchange, thus resulting in anaerobic respiration and elevated ethanol and acetaldehyde contents.

Packaging

Proper or scientific packaging of fresh fruits and vegetables reduces the wastage of commodities by protecting them from mechanical damage, pilferage, dirt, moisture loss and other undesirable physiological changes and pathological deterioration during the course of storage, transportation and subsequent marketing. For providing uniform quality to packed produce, the commodity should be carefully supervised and sorted prior to packaging. Packaging cannot improve the quality but it certainly helps in maintaining it as it protects the produce against the hazards of transportation.

Transportation

Mechanical damage to packages occurs particularly during handling and transportation. Rail, road, sea and air transport may all be used to move produce to its destination. Air-transport relies on short journey time to maintain produce quality. The packaging requirement during surface transport are generally greater than by air owing to longer time taken for the journey, higher humidity and usually greater stack heights. The use of pallets and mechanical aids can reduce handling damage to the package considerably. It is very important that the package maintains its integrity throughout the journey.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain briefly the important changes take place in harvested fruits and vegetables.

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2. Why pre-cooling is important for harvested fruits and vegetables?

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3. Discuss the unit operations, which are important for handling of fruits and vegetables.

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10.6 COLD STORAGE

Fresh produce changes in quality and quantity between harvest and consumption. These losses have been observed to the tune of 20-50 per cent particularly in developing country depending upon the commodity. Fresh produce like fruits and vegetables and ornamentals are living tissues, which are subjected to continuous change after harvest due to inadequate handling, packaging, transport and storage. Deterioration in fruits and vegetables occur mainly through the process of physiological ageing and water loss. The rate at which the stored product respires is a major factor in determining the pace of physiological ageing.

The deterioration in the agricultural produce of high value (milk, meat, fish, fruits, and vegetables) depends largely on storage temperature. One way to minimize deterioration reduce losses consists of lowering their storage temperature to an appropriate level. The storage of foods for extended periods at lowered temperatures is called as cold storage.

Refrigeration or Chilling

Chilling temperatures are obtained by means of ice or mechanical refrigeration. Fruits, vegetables and their products and other high value foods can be stored for a few days to many weeks when kept at chilling temperature. It is necessary to refrigerate fruits and vegetables as soon as they are harvested, fish as soon as they are caught and meat as soon as slaughter has taken place under good hygienic conditions, eggs recently laid, etc. to maintain the quality of the foods. It is important to cool the produce before refrigeration, maintain RH conditions for the food, and carry out renewal of air.

Freezing

Freezing method is most harmless method of storage of food for longer duration. At temperature below the freezing point of water (-18^0 to -40^0 C) growth of microorganisms and enzyme activity are reduced to a minimum. Most perishable foods can be preserved for several months if the temperature is brought down quickly (quick freezing) and the food is kept at these temperatures. Quick frozen foods maintain their quality and freshness when they are thawed because only very small ice crystals are formed when foods are frozen in this manner.

Table 10.4: Practical storage life of some frozen products

Product	Practical storage Life (in months)		
	-18^0C	-25^0C	-30^0C
Fruits			
Peaches, apricots or cherries (sweet or sour) in sugar	12	18	24
Raspberries or strawberries in sugar	18	<24	>24
Citrus or other fruit concentrates	24	>24	>24
Vegetables			
Broccoli	15	24	>24
Carrots	18	>24	>24
Cauliflower	15	24	>24
Peas	18	>24	>24

Raw meat and meat products			
Beef carcass	12	18	24
Veal carcass	9	12	24
Pork carcass	6	12	15
Poultry, chicken and turkeys eviscerated (packaged)	12	24	24
Fried chicken	6	9	12
Whole eggs, liquid	12	24	>24
Marine products			
Fatty fish	4	8	12
Lean fish	8	18	24
Milk products			
Butter from pasteurized and matured cream	8	12	15
Cream	6	12	18
Ice-cream	6	12	18
Bakery and confectionery			
Cakes-cheese, sponge, chocolate, fruit, etc	12	24	>24

10.7 PROTECTION AND PRESERVATION TECHNIQUES

Foods are perishable and hence cannot be stored at ordinary temperatures for any length of time. So there comes the need of protection and preservation. It becomes necessary to take the preventive measures to increase the shelf life, or to treat these commodities with some life enhancer or processing them to various products. In the preservation of food, the following methods are involved:

I. Prevention or delay of microbial decomposition

   a) by keeping out microorganisms (asepsis- packaging prevents entry of microorganisms in food, e.g. canned peas);

   b) by removal of microorganisms, e.g. filtration;

   c) by hindering the growth and activity of microorganisms, e.g., by low temperature, drying, anaerobic conditions, chemicals or antibiotics; and

II. By killing the microorganisms, e.g., by heat or irradiation.

III. Prevention or delay of self-decomposition of food

   a) by destruction or inactivation of enzymes, e.g., by blanching or boiling;

   b) by prevention or delay of chemical reactions, e.g., prevention of oxidation by means of an antioxidant.

IV. Prevention of damage by insects, animals, mechanical causes, etc.

Various methods generally used for preservation of foods are as under:

I. Preservation by High Temperature: Two common methods of preservation by high temperatures are preservation are usually: pasteurization and sterilization.

a) Pasteurization

Pasteurization destroys pathogenic microorganisms and extends shelf life of the product by decreasing the microbial population and inactivation of enzymes, for example, pasteurized milk and other dairy products, beer, fruit juices and aerated drinks. Dried fruits like raisins, apricots and dates can also be pasteurized in the package.

b) Sterilization

Sterilization means the destruction of all viable microorganisms. The time and temperature necessary for sterilization vary with the type of food. Vegetables like green peas, beans, okra etc being non acidic contains more starch than sugar, require higher temperature to kill the spore forming organisms. Continuous heating or 30 to 90 minutes at 116^0 C is essential for their sterilization. Temperature above 100^0 C can only be obtained by using steam pressure sterilizers such as autoclaves.

Aseptic Canning

Aseptic Canning is a technique in which food is sterilized outside the can and then aseptically placed in previously sterilized cans, which are subsequently sealed in an aseptic environment, e.g., fluid and semi fluid products. The temperature employed may be as high as 149^0 C and sterilization takes place in 1 or 2 seconds.

Hot Pack or Hot Fill

Hot pack refers to the filling of previously pasteurized or sterilized food while still hot, into clean but not necessarily sterile containers under clean but not necessarily aseptic conditions, e.g. filling of hot jams in jars. Heat of the product and some holding time before cooling render the container sterile.

II. Preservation by Low Temperature

Microbial growth and enzymatic recitations are retarded in foods stored at low temperatures. Low temperatures can be obtained by (a) refrigeration or chilling (0-5^0C) suitable for storage of potatoes, apples and other perishables, and (b) freezing (-18 to -40^0 C) suitable for storage of most of the perishables.

III. Preservation by Chemicals

Certain chemicals when added in small quantities can hinder undesirable chemical reaction in food by interfering with cell membrane and enzymatic activity of microorganisms or their genetic mechanisms and acting as antioxidants. Benzoic acid, potassium metabisulphite, sorbic acid, calcium propionate are some of the chemicals used as preservative.

The development of off flavours (rancidity) in edible oils is prevented by the use of butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT) or lecithin, which act as antioxidants.

IV. Preservation by drying

When the moisture content of food is brought down below a certain level, microorganisms are unable to grow. Moisture can be removed by heat application as in sun drying or by mechanical drying (dehydration), e.g. dried green peas, cauliflower and raw mango, and fruit juice powder, etc.

V. Preservation by filtration

In this method, the juices are clarified by settling or by using ordinary filters and then passed through special filters, which are capable for retaining yeasts and bacteria. Various types of germ proof filters are used for this purpose.

VI. Preservation by Carbonation

Carbonation adds to the life of a beverage and contributes in some measures to its tang. Another advantage of carbonation is the removal of air thus creating an anaerobic condition, which reduces the oxidation of ascorbic acid and prevents browning.

VII. Preservation by Salt or Sugar

Salt at a concentration of 15 to 25 per cent is sufficient to preserve most products by: (i) causing high osmotic pressure resulting in the plasmolysis of microbial cells, (ii) dehydrating food as well as microorganisms by drawing out and tying up the moisture (iii) ionizing to yield the chloride ion which is harmful to microorganisms, (iv) reducing the solubility of oxygen in water, sensitizing the cells against carbon dioxide, and interfering with the action of proteolytic enzymes. Sugar absorbs most of the available water resulting very little water for microbial growth hence their multiplication is inhibited and even those already present die out gradually. Thus sugar acts as preservative by osmosis as in case of jam, jelly, candy, marmalade, etc.

VIII. Preservation by Fermentation

Decomposition of carbohydrates by microorganisms or enzymes is called 'fermentation'. By this method, foods are preserved by the alcohol or organic acid formed by microbial action. The keeping quality of the alcoholic beverages (wine, beers), vinegar and fermented pickles depends upon the presence of alcohol, acetic acid and lactic acid, respectively. About 2 per cent acetic acid prevents spoilage in many products.

IX. Preservation by Acids

Acidic conditions inhibit the growth of many microorganisms hence organic acids are added to or allowed to form in foods to preserve them. Acetic acid in pickles, citric acid in squashes, jam and jellies, lactic acid are commonly used for preservation.

X. Preservation by oil and spices

A layer of oil on the surface of any food produces anaerobic conditions, which prevents the growth of moulds and yeasts. Thus pickles in which enough oil is added to form a layer at the top can be preserved for long periods. Spices like turmeric, pepper, and asafoetida have very little bacteriostatic effect but their primary function is to impart their characteristic flavour to food.

XI. Preservation by Antibiotics

Certain metabolic products of microorganisms have been found to have germicidal effect and are termed as antibiotics. Nisin, an antibiotic used in canning of mushrooms, tomatoes and milk products. Subtilin is used for the preservation of asparagus, corn, and peas. *Pimaricin* can be used for treating fruits and fruit juices. At present these three antibiotics are permitted only in such foods. Residual antibiotics are expected to be destroyed during cooking as these foods are expected to cook prior to consumption.

XII. Preservation by irradiation

The ionizing radiations (gamma rays or electro beams) can be used for sterilization of foods in hermetically sealed packs, reducing the spoilage flora on perishable foods, elimination of pathogens in foods, control of infestation in stored cereals, prevention of sprouting of potatoes, onion etc. The irradiation of food can be considered to a method of 'cold sterilization', i.e. food is free of microorganisms without high temperature treatment. This method has not yet gained general acceptance due to the unacceptable flavour of some irradiated food and fear of hazard.

10.8 EVAPORATIVE COOLING AND STORAGE

Temperature and moisture content are two most important parameters, which control the rate of decay of food commodities during storage. The higher the temperature the more is the rate of respiration and other biochemical processes, and the food is more likely to develop abnormalities with resultant loss of quality and nutritive value. The vital activities of the tissues such as transpiration, respiration and ripening etc. continue even after harvest. The high moisture content of the horticultural commodities accelerates these reactions making them highly perishable. Very low humidity in the storage space causes undesirable moisture loss from the commodity leading to desiccation and shrivelling. Thus, the principal aim of storage in fresh form is to control wilting and shrinkage alongwith the above undesirable physiological and biochemical changes and infections. This can be achieved by maintaining lower temperature and high humidity conditions through evaporative cooling.

Evaporative cooling is the adiabatic saturation of moist air. It is a thermodynamic process, where a part or all of the sensible heat of moist air is converted to latent heat, thereby, producing a reduction in temperature. Evaporation of water produces a considerable cooling effect and the effect increases with increase in the amount of evaporation. Theoretically, the lowest temperature that can be achieved by the evaporation of water is the wet bulb temperature of the moist air. Evaporative cooling has been extensively utilized for creating a modified atmosphere in an enclosure for crop growing, livestock housing or storage of horticultural produce. Evaporative cooling has also been recommended for removal of field heat from produce on the farm and for short duration storage after it is removed from the cold stores before distribution.

Evaporative cool chambers maintain 10-15^0 C lower temperature compared to field temperature, depending on the season and also maintain around 90 per cent relative humidity. The fruits and vegetables can be stored in plastic crates in the chamber. The shelf life of some fruit and vegetables in the cool chambers have been observed to increase from 3 to 90 days as compared to storage at room temperature.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are different principles of food preservation? List out with examples.

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2. How the temperature effect the storage of fruits and vegetables, explain in brief.

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10.9 LET US SUM UP

Fruits and vegetables are highly perishable commodities. Fresh produce changes in quality and quantity between harvest and consumption. These changes depend upon a number of factors. The quantitative losses have been observed to the tune of 20-50 per cent mainly because of inappropriate handling, packaging, transport and storage of the fresh produce. Deteriorative changes in fruits and vegetables occur mainly due to the action of microorganisms, storage conditions like temperature, oxygen, light, duration of storage, characteristics of the food, insects, pest, diseases etc.

Post harvest handling is one of the major factors that affect the overall quality and losses during transport and marketing. Spoilage in fruits and vegetables depends largely on storage temperature. Deteriorative changes and quantitative losses can be reduced significantly by lowering the storage temperature to an appropriate level. The storage of foods for extended periods at lowered temperatures is called as cold storage.

Most of the fruits and vegetables cannot be stored for too long. So there arises the need of protection and preservation. Fruits and vegetables can be preserved by high temperatures (as in case of pasteurization, sterilization, canning), low temperature (refrigeration or freezing), preservatives, removal of moisture, use of salt, sugar, acids, oils, antibiotics, and irradiation.

10.10 KEY WORDS

Canning : the process of preserving food by sterilization at >100^0 C and cooking in a sealed metal can, which destroys bacteria and protects from contamination.

Carbonation : is the process of dissolving sufficient carbon dioxide in water or beverage so that the product when served gives off the gas as fine bubbles and has a characteristic taste, e.g. carbonated fruit beverages.

Maillard reaction : the reaction between lysine (an amino acid in protein) and sugars is known as Maillard reaction. This deteriorative change takes place on heating or prolonged storage.

Pasteurization : when food is heated in containers or by other method to a temperature below 100^0 C for a definite period of time, the process is known as pasteurization.

Respiration : oxidative breakdown of complex materials, present in cells, such as carbon dioxide and water, with the production of energy and other molecules that can be used by the cell for synthetic reactions.

Spoilage : is a condition produced by excessive growth of microorganisms leading gradually to decay or decomposition or by other physical and chemical causes.

10.11 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Undesirable changes in foods.

   Food spoiled due to action of microorganisms, insects, pests, enzymes and other factors. See sub-sec. 10.3.

2. Physical factor, physiological factors, thermal factors, microbial factors, chemical factors, insects, pests, diseases. See Sub-sec 10.3.

3. Rodents contaminate the food with their urine and droppings.

   Rats can contaminate the food with microorganisms. See Sub-sec 10.3.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Respiration.

   Changes in water content.

   Organic acids and starch content decreases. Sugar content increases.

   See sub-sec 10.4.1.

2. Reduces field heat.

   Reduces the rate of deterioration. See sub-sec 10.4.

3. Pre-cooling, washing, cleaning, trimming, sorting, grading, curing, sizing, waxing, packaging. See sub-sec 10.4.

Check Your Progress Exercise 3

Your answer should include the following points:

1. Prevention or delay of microbial decomposition

   By killing the microorganisms.

   Prevention or delay of self-decomposition of food. See sub-sec. 10.7.

2. High temperature enhances decay.

   Low temperature reduces losses and enhances shelf life. See sub-sec. 10.7 and 10.8.

10.12 SOME USEFUL BOOKS

1. Srivastava, R.P. and Kumar Sanjeev (2002) Fruit & Vegetable Preservation (Principal and Practices 3rd Revised and Enlarged Edition), International Book Distributing Co.

2. Thompson, A.K. (1996) Post Harvest Technology of Fruit and Vegetables, Blackwell Science Ltd., London.

3. Wills, R., McGlasson, B., Graham, D. and Joyce, D. (1998) Post-harvest an Introduction to the Physiology and Handling of Fruit, Vegetables & Ornamentals, CAB International, Australia.

4. Wills, R.B.H., McGlasson, Graham D., Lee, T.H. and Hall, E.G. (1989) Post Harvest an Introduction to the Physiology and Handling of Fruit and Vegetables. CBS Publishers and Distributors, Delhi.

UNIT 11 ANTI-NUTRITIONAL FACTORS, FOOD CONTAMINANTS AND TOXIC ELEMENTS

Structure

11.0 OBJECTIVES

After reading this unit, you should be able to:

- describe food contamination, factors contributing contamination and methods of prevention;
- list the anti-nutritional factors in food;
- discuss food born illness; and
- state deficiency diseases.

11.1 INTRODUCTION

Foods are exceedingly complex mixtures of chemicals substances. Apart from containing nutritionally important constituents, some foods also contain substances, which are harmful. The presence of nonnutritive constituents in foods represents potential health risks of different characters and magnitudes to persons consuming them. If such food is ingested, it can cause food poisoning and infection. Food poisoning could be caused by ingestion of foods containing certain chemicals, toxic plants or animals, toxins produced by bacteria and ingestion of animal parasites. Pathogenic microorganisms may enter foods through poor handling and grow in it. When such contaminated food is ingested, it could cause food infections. Hence, food safety should be a major concern of processor for the public health.

11.2 ANTI-NUTRITIONAL FACTORS

11.2.1 Anti-Nutritional Factors in Plant Foods

Plants are capable of synthesizing a multitude of chemical that cause toxic reaction when consumed. Pulses contain a number of toxic factors, such as protease inhibitors, lathyrogens and favism agents, cyanogens, haemagglutinins and saponins. Some of these toxins are also present in other foods, e.g., protease inhibitors in cereals and potatoes. Solanine, ordinarily the green parts of the potato are removed with the peel, is a toxicant in potatoes. Goitrogens (cause thyroid enlargement) are present in cabbage and related species, rapeseed and mustard. Some varieties of mushroom (e.g. Amanita) are poisonous. Oxalic acid present in spinach, beet etc may cause oxalic poisoning. Soybean contains trypsin inhibitor that affects protein metabolism. Cassava and Lima beans contain linmarin, a toxic glycoside. Lathyrism is a neurological disease caused by the ingestion of *Lathyrus sativus* (khesari dhal) for a period of 6 months or more. Favism agents in fava beans, gossypol in cottonseed are also potent toxic substances.

The active flavoring principles present in some spices may have toxic effects if consumed habitually over long periods or in excessive amounts. Active principles in some of the foods are allyl isothiocyanate in mustard, capsaicin in chillies, myristicin in nutmeg and mace, etc.

11.2.2 Toxicants in Animal Foods

The ingestion of shellfish (clams, mussels) results in paralytic shellfish poisoning. Saxitoxin, an extremely toxic metabolite, is p roduced from the plankton. The toxin resists ordinary cooking procedures. Sea food poisoning, for examples, ciguatera poisoning, moray eel poisoning, scombroid poisoning, puffer fish poisoning, cephalopod poisoning, is mostly prevalent in the areas where marine organisms constitute about 10 per cent of the diet.

11.3 CONTAMINATION OF FOOD BY MICROORGANISM, PATHOGENS

A large number of careless practices cause contamination of food with potentially pathogenic microorganisms. The more common ones are unhygienic practices of food handling, personnel handling food suffer from communicable diseases, cross contamination of food, contaminated water and containers, soil adhering to foods, insects, droppings of rodents.

Contamination by Bacteria

Certain bacteria release poisons known as toxins. Some toxins produced by *Clostridium botulinum* are often cause death of persons consuming food contaminated with this organism. The bacteria such as Staphylococcus aureus and Bacillus cereus produce toxins in food during multiplication or sporulation. Although cooking may destroy these bacteria but the toxin is unaffected and can still cause the problems if food is eaten. Endotoxin are generally produced by bacteria such as *Salmonella* in the intestines of persons consuming food contaminated with such organisms.

Contamination by Moulds

Almost any food can be invaded by mould growth. Moulds cause various degree of visible deterioration and decomposition of foods. Moulds may produce abnormal flavours and odours due to fermentative, lipolytic, and proteolytic changes caused by enzymatic reactions with carbohydrates, fats, and proteins, respectively in foods.

Contamination by Yeasts

Food that is highly contaminated with yeasts will frequently have a fruity odour. Yeasts can grow in a product with low sugar concentration. Most of them do not develop in solutions containing more than 66% sugar or 0.5% acetic acid. Boiling destroys the yeasts cells and spores completely. Foods liable to be spoiled by yeasts are fruit juices, syrups, molasses, honey, jams and jellies.

Contamination by Viruses

Viruses are transmitted to food by workers who are carriers. An infected food handler can excrete the organism through the faeces and respiratory tract infection. The inability of host cells to perform their normal function causes illness due to viral infection.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. 'Non-nutritive constituents of food can create potential health risks', justify.

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2. Write some of the important anti-nutritional substances present in vegetables.

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3. Define endotoxins. List the factors responsible for food contamination.

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11.4 FOOD INTOXICANTS

The undesirable constituents that affect the safety of foods include toxicants naturally occurring in foods, toxins resulting from microbial growth, environmental contaminants such as processing and accidental contaminants and chemical contaminants.

Naturally occurring toxicants in plant and animal foods

Foods contain thousands of compounds that are potentially toxic. For example protease inhibitors, lathyrogens, favism agents, cyanogens, haemagglutinins and saponins in pulses, solanine in potatoes, goitrogens in cabbage, rapeseed, etc., trypsin inhibitor in soybean, beta oxalyl amino alanine in khesari dhal, linmarin in cassava and lima beans, Favism agents in fava beans, gossypol in cottonseed are potent toxic substances. Some spices contain active principals (e.g., allyl isothiocyanate in mustard, etc.) may have toxic effects. Paralytic shellfish poisoning from oysters, calms, mussels, and scallops has caused many fatal illness. Saxitoxin, an extremely toxic metabolite, is produced from the plankton.

Microbial Toxins

Microorganisms promote desirable changes in foods under controlled conditions. However, they also cause harmful effect and are involved in most cases of food poisoning.

Bacterial food intoxication: Staphylococcal poisoning occurs abruptly after ingestion of food containing the enterotoxin, produced by staphylococci present in semisolid foods. Foods such as corn, peas, meat, fish are likely to be contaminated with the spore of Clostridium botulinum. They act on nervous system and are potent poisons and cause a disease known as botulism. The food infected with Bacillus cereus, if consumed is also harmful.

Some species of fungi such as Aspergillus flavus, Aspaergillus parasiticus (produced aflatoxins) Claviceps purpurea, Fusarium species produce toxins in foods infected with them and make the foods unfit for consumption.

Environmental Contaminants

These include residues that become part of food as a result of processing, handling and distribution of food. For examples, ethylene oxide used as fumigants to sterile some food reacts with inorganic chlorides to form ethylene chlorohydrin, which is toxic. During smoking of meat and fish for preservation and flavouring, these foods get contaminated with polycyclic aromatic hydrocarbons (e.g. benzopyrine), many of which are carcinogenic.

Metals, find their way into foods through air, water, soil, industrial pollution and many other routes, when present beyond the permissible limit, are toxic. Mercury, cadmium, lead, tin, etc. are the toxic metals present in foods.

Other contaminants from food processing such as lubricants, boiling water additives, packaging material, inside coating of the packaging materials, etc. may contaminate the food and their products and make them unfit for consumption.

11.5 MYCOTOXINS

Mycotoxins are toxic metabolites produced by various moulds when they grow on agricultural products before or after harvest, and during transportation or storage. Some moulds such as Aspergillus species and Penicillium species can invade grains after harvest and produce mycotoxins, while others such as Fusarium species, infect grains and produce mycotoxins before harvest. Mycotoxins remain in the food long after the mould producing them has died and can therefore, be present in foods that are not visibly mouldy. Further many mycotoxins, but not all, are stable and survive the usual conditions of cooking or processing.

Mycotoxins are undesirable because of their adverse effect on both human and animal health. Many mycotoxins have been found to occur naturally in a large number of commodities, but only few of these are widely accepted as causing significant food safety risks. Food grains, especially rye, bajra, sorghum and wheat have a tendency to get infected with the ergot fungus, Claviceps purpurea. Consumption of ergot infected grains leads to ergotism. Mycotoxins produced by certain moulds, Aspergillus flavus and Aspergillus parasiticus are known as aflatoxins. These fungi develop in many foods particularly in maize, sorghum, groundnut, etc. under improper storage conditions and produce aflatoxins of which B_1 and G_1 are the most potent hepatotoxins, in addition to being carcinogenic.

Moisture content of foods above 16 per cent and temperatures ranging from 11 to 37^0 C favour toxin formation. Fungal contamination can be prevented by proper storage after drying the grains to 10 per cent moisture level.

11.6 FOOD POISONING AND FOOD INFECTIONS

11.6.1 Food Poisoning

Food poisoning is an acute gastro-enteritis or any other disorder caused by ingestion of food contaminated with either living bacteria or their toxins or inorganic chemicals and poisonous plant and animal foods.

i) Food poisoning by microorganisms

Botulism is a severe form of food poisoning caused by ingestion of inadequately cooked canned food (beans, peas, etc.) contaminated with bacteria; Clostridium botulinum. The symptoms of botulism occur 18 to 36 hours after ingestion of contaminated food and begin in gastrointestinal tract. The principal hazard is the effect on the nervous system. Death may occur as a result of respiratory paralysis and cardiac failure.

Staphylococcal food poisoning is the most common form of food poisoning which occurs after ingestion of food contaminated with Staphylococcus aureus. Staphylococcus contamination of food may either be from human or animal sources. Some strains of *Staphylococcus aureus* can produce an enterotoxin. Staphylococcal food poisoning can be characterized by salivation, nausea, vomiting, abdominal cramps and diarrhoea. Pasteurization kills all the Staphylococci that may be present in foods but toxins may not be destroyed by pasteurization or ordinary boiling.

Salmonella food poisoning caused by the ingestion of foods particularly commercially prepared animal foods, contaminated with S. typhimurium, S. cholera-suis and S. enteritis besides many others. Salmonellosis may be characterized by enteric fever, gastro-enteritis.

Clostridium perfringens food poisoning: C. perfringens has been found in faeces, soil, water and air. The majority of this type of poisoning has been associated with ingestion of fresh or frozen meat, meat preparations and poultry. The common symptoms of this poisoning are diarrhoea, abdominal cramps and fever, occurring 8 to 24 hours after consumption of the food. The bacteria are destroyed by ordinary cooking temperature but spores survive at this temperature and need thorough cooking.

Cereus food poisoning caused by Bacillus cereus and their toxin, found in raw, dried and processed foods. The spores can survive at cooking temperature and multiply rapidly when food is held at room temperatures. The poisoning is characterized by gastro-intestinal tract symptoms.

Some of the species of fungi such as *Aspergillus flavus*, *Aspergillus parasiticus*, *Claviceps purpurea*, *Fusarium* species produced toxins in foods and make those foods unfit for human consumption.

ii) Contaminants arising from processing, accidental contaminants and chemicals

These include residues that become part of food as a result of processing, handling and distribution of food, e.g., fumigants. Ethylene oxide is a commonly used fumigant. Ethylene oxide reacts with inorganic chlorides to form ethylene chlorohydrin, which is toxic. Solvents like trichloroethylene, used for extraction of oil from oilseeds reacts with the substances and produce a toxic product.

During smoking of meat and fish for preservation and flavouring, these foods get contaminated with polycyclic aromatic hydrocarbons (e.g. benzopyrine), many of which are carcinogenic.

Metals find their way into foods through air, water, soil, industrial pollution and many other routes. Metals (mercury, lead, tin, aluminum, etc.) beyond the permissible limits are toxic.

Poisoning by chemicals is not very common. Poisonous chemicals like arsenic, cadmium, antimony can enter foods through improperly coated utensils. Insecticide and pesticides (malathion etc.) residues can also cause food poisoning if contaminated food is consumed without washing.

iii) Poisonous plants and animals

Certain varieties of mushrooms are very poisonous and could be fatal if consumed. Snakeroot poisoning could result from drinking milk from cows that have fed on this weed. Seafood such as mussels and clams sometimes contain a poisonous alkaloid. Death camas contains a poisonous alkaloid that decrease blood pressure if consumed. Bush tea contains toxic factors, which are known to cause occlusive disease of the liver, often leading cirrhosis. Pulses contain a number of toxic substances such as protease inhibitors, lathyrogens and favism agents, cyanogens, haemagglutinins and saponins. Saponins goitrogens, oxalic acid present in some foods can cause poisoning if consumed in large quantities. Gossypol is a toxicant found in cottonseed. Sea foods poisoning, toxicants present in certain spices and flavours. Toxic substances found in certain food fats cause food poisoning when consumed in large amounts.

11.6.2 Food Infections

Pathogenic microorganisms and parasites may enter foods through poor handling and grow in it. Food containing a large number of pathogens if ingested can cause food infections. Food borne infections are especially prevalent in communities with inadequate facilities for storing foods and insanitary water supplies and lavatories. The principal types of infectious organisms that may cause diseases are: bacteria, moulds and viruses.

Bacterial food infections result from the ingestion of large amount of viable bacteria, which multiply inside the host and cause infections. Some of the common infectious diseases caused by bacteria are:

- Cholera is one of the most acute and violent infections, characterized by fever, severe diarrhoea, abdominal cramps, vomiting, intense thirst followed by collapse. Cholera spreads from infected person and faecal-contaminated food and water.

- *Bacillus cereus* infection characterized by severe vomiting 1 hour after ingestion or diarrhoea later.

- Escherichia coli food infection is spread by contaminated food and water. It is characterized by gastroenteritis and most common infection in infants.

- Salmonellosis is characterized by diarrhoea, abdominal cramps and vomiting, which usually lasts for 2 to 3 days. Salmonella bacteria grow rapidly in cooked eggs, meat, custards and salads, which have been left at room temperature for several hours.

Some other bacterial infections, which are caused by ingestion of contaminated food, are tuberculosis and typhoid.

Many diarrhoeal diseases, viral hepatitis, gastroenteritis, etc. are transmitted primarily by faecal-oral route. Faecal oral transmission may be water born, food born, or direct transmission, which implies an array of other faecal-oral routs such as via fingers, or fomites, or dirt.

Parasitic Infestation of Foods

Many protozoa, helminthes (worms) gain admission to the body by means of food and cause injury to the intestinal lining and sometimes other tissues. Amoebiasis is a common infection of gastrointestinal tract, caused by potentially pathogenic strain of Entamoeba histolytica. The helminthes that frequently invade the intestinal tract include nematodes (round worms), cestodes (tapeworms), and trematodes (liver, intestinal, and lungs flukes). Tricinosis, one of the most serious infestation results from ingestion of raw or partially cooked pork infected with Trichinella spiralis, a very minute roundworm. Trichinella is destroyed by cooking pork, until no trace of pink remains. Foods act as a carrier for the parasites but none of these organisms grow in the food as such. Usually such contamination occurs due to poor handling of food and preparation.

11.7 FOOD BORN DISEASES

Food borne disease is caused by agents that enter the body through the ingestion of food. Food borne diseases may be classified as:

A) Food Borne Intoxications

i) Due to naturally occurring toxins in some foods, e.g., lathyrism, endemic ascites, etc.

ii) Due to toxins produced by certain bacteria, e.g., botulism, staphylococcal food poisoning.

iii) Due to toxins produced by some fungi e.g., aflatoxins, ergot, fusarium toxins, etc.

iv) Food borne chemical poisoning

- Heavy metals, e.g., mercury (in fish), cadmium (in certain shellfish), and lead (in canned food)
- Oils, petroleum derivatives and solvents
- Migrant chemicals from packaging materials
- Pesticide residues (DDT, BHC)

B) Food borne infections

i) *Bacterial infections:* typhoid, cholera, salmonellosis, shigellosis, etc.

ii) *Viral infection:* viral hepatitis, gastroenteritis

iii) *Parasitic infestations:* ascariasis, amoebiasis, trichinosis, etc.

(Details about food borne diseases was covered under food toxins, food poisoning and food infections)

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is food poisoning? Explain with the help of examples.

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2. What do you understand by food borne diseases? Write the name of some common food borne infections.

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3. What are mycotoxins? Write a brief note on aflatoxins.

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4. What are different environmental contaminants that make the food unfit for consumption?

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11.8 METHODS OF PREVENTING FOOD CONTAMINATION

Contamination can be reduced through effective housekeeping and sanitation, protection of food during storage, proper disposal of garbage and litter, and protection against contact with toxic substances.

The Environment

Only cleaned hands should touch food during handling and processing. A processed product should be kept covered to prevent the entry of dust or other things. If the nature of food does not permit this kind of protection; it should be placed in an enclosed, dust free cabinet at appropriate temperature. Equipment and utensils for food processing, packaging, preparation, and service should be cleaned and sanitized between uses.

Storage

Storage facilities should provide adequate space with appropriate control and protection against dust, insects, rodents, and other extraneous matter. Organized storage layouts can reduce contamination and facilitate cleaning. In addition storage area floors shelves and/ or racks should be cleaned regularly. Waste materials should not be accumulated in the food storage area.

Litter and Garbage

Waste and refused materials (used packaging materials, containers and waste products) should be placed in appropriate containers for disposal. These receptacles should be seamless, with close fitting lids. Plastic liners are inexpensive and provide added protection. All receptacles should be washed and disinfected regularly. Containers kept in food processing and food preparation areas should not be used for garbage or litter, other than that produced in those areas.

Toxic Substances

Poisons and toxic chemicals should not be stored near food products. In fact, only chemicals (well labelled) required for cleaning should be stored in the same premises. Only cleaning compounds, supplies, utensils, and equipment approved by regulatory or other agencies should be used in food handling, processing, and preparation.

11.9 DEFICIENCY: PROTEIN, VITAMIN AND MINERAL – CONSEQUENCES AND CORRECTIVE MEASURES

As a consequence of dietary deficiency, several nutritional problems are encountered namely (i) PEM (ii) vitamin A deficiency, (iii) iron deficiency anaemia, (iv) iodine deficiency, (v) vitamin B-complex deficiencies.

Protein Deficiency

Protein energy malnutrition (PEM) is the name given to various degree of nutritional disorders caused by inadequate quantities of protein and energy in the diet of young children. This leads to various degree of growth retardation. When growth retardation is severe, functional deficiencies, like resistance to infection, poor intellectual development and body may have wasted away. Kwashiorkor and marasmus are two clinical forms of PEM at opposite poles of a single continuum. Kwashiorkor (growth failure, oedema, diarrhoea, fatty liver, dermatitis and other symptoms) occurs when there is a lack of protein in the diet but calories or energy in the form of carbohydrates is available in sufficient quantity. However, when both protein and energy are insufficient, over prolonged periods, a condition known as marasmus (growth failure, wasting of muscles, and dry and atropic skin and other symptoms) occurs in children. Both kwashiorkor and marasmus can be complicated with other infections due to intestinal parasites and bacteria.

The dietary management along with medical treatment for infection, if any is necessary for rapid recovery of the child with PEM. The diet should be rich in easily digestible proteins (4-5 g/ kg normal body weight of the child) of high nutritive quality (from milk and milk product, legumes, sprouts etc.), calories (140 Kcal/ kg body weight) and all dietary essentials (vitamin A and iron supplementation).

Vitamin Deficiencies

Vitamin A deficiency is a major nutritional problem in young children leading to blindness. Night blindness (inability to see in dim light), Conjuctival xerosis (conjuctiva becomes dry and non-wettable, appears muddy and wrinkled), Bitot's spot (triangular, pearly-white or yellowish, foamy spots on the bulbar conjuctiva on either side of the cornea), corneal xesosis (cornea appears dull, dry, non wettable and eventually opaque) and keratomalacia (cornea may become soft and burst open) are important deficiency states due to vitamin A deficiency. The person with vitamin A deficiency should be given well balanced diet including green leafy vegetables and yellow and orange fruits in sufficient quantities with the vitamin A supplementation.

Vitamin D deficiency causes Rickets in children (characterized by enlarged joint, bowed legs, knocked knees, bulging forehead, pot belly, delayed eruption of temporary teeth, muscular hypotonia etc.) and Osteomalacia in adults, in which bones soften, become distorted, and fracture easily. The subjects (children or adults) should be given a well balanced diet containing plenty of milk, ragi, and green leafy vegetables along with calcium and vitamin D supplementation.

Vitamin C deficiency produces the disease scurvy characterized by swollen and inflamed gums, loss of weight, anaemia, poor wound healing, pain in joint and muscles. Severe form of scurvy is fatal. In addition to well balanced diets with sufficient amount of locally available fruits and germinated legumes, vitamin C supplementation is important.

Vitamin B-complex deficiencies commonly encountered are riboflavin deficiency leading to angular stomatitis, glossitis and cheilosis; thiamine deficiency leading beri-beri and niacin deficiency (Pellagra). Thiamine deficiency is prevalent in areas where polished rice is the staple food. Inclusion of under milled, or parboiled rice, whole wheat and wheat products, nuts, legumes could help to remove thiamine deficiency. Use of milk and milk products, eggs, green leafy vegetables could prevent riboflavin deficiency. Groundnuts are rich in niacin. Use of combination of cereals, pulses and inclusion of groundnuts would help in preventing vitamin B-complex deficiency.

Mineral Deficiencies

Nutritional aneamia and iodine deficiency are the major public health problems due to mineral deficiencies. Aneamia affects all segments of population in general and children, women and pregnant women in particular. Anaemia may be due to deficiency of iron, or folic acid or vitamin B_{12}. The incidence of anaemia can be reduced by inclusion of leafy vegetables, pulses, whole grains and vitamin C rich seasonal fruits in diet. Since change in dietary habits is a slow process, some interim public health measures have been taken to reduce the incidence of anaemia. These include distribution of tablets containing iron and folic acid at primary health centers. In order to combat and prevent iron deficiency anaemia, fortification of a universally consumed dietary item with iron can be one of the most effective methods.

The Iodine deficiency in man leads to a number of disorders, which include goiter, mental retardation, cretinism, myxoedema, and neuropsychic retardation. The simplest way of eradicating iodine deficiency is by consumption of iodized salt.

11.10 METHODS OF NUTRIENT RETENTION DURING PROCESSING AND STORAGE

Using food preparation methods maximizing nutrient retention is most important to maintain the quality of foods. The processing methods generally used in food preparation; also affect the nutritive quality of various foodstuffs.

i) Nutrients retention during milling

Milling of cereals like paddy to get rice causes considerable loss of vitamins, minerals and proteins. Parboiling of paddy can significantly reduce the nutritional losses during milling of paddy. During parboiling of paddy, B-vitamins present in the bran gets fixed to the grain and hence not removed during milling. Washing of rice before cooking in limited amounts of water also reduce the loss of thiamine due to leaching.

Nutritional loss also occurs during dehulling of pulses. The dehulling losses, in terms of broken and powder fractions can be reduced by following suitable pre-milling treatment (heat treatment or oil treatment etc.) and conditioning of legume seeds before dehulling.

ii) Prevent nutrients from leaching

Water leaches out some vitamins and minerals from the foods. Presoaking of food grains has negligible effect on nutrients such as proteins and fats but digestibility of starch improves. If soaking water discarded, reduction in some nutrients such as minerals and B-complex vitamins will occur. Rice should not be washed for longer time to avoid the loss of thiamine and niacin. The nutrients are also lost if water in which vegetables are cooked, discarded. Vegetables and fruits should be washed before cutting to avoid the leaching of nutrients in washing water.

iii) Avoid excessive heat treatment

Excessive heat destroys heat sensitive vitamins and decreases the protein quality. Preparing food in smallest amount of water at optimum temperature for the shortest time does least nutritional damage. Reheating of food products will add to the loss of nutrients. If required microwave heating for a few seconds may serve the purpose.

iv) Save foods from exposure to oxygen and light

Oxygen in the air and light decreases the amount of vitamins A, B_{12}, C, D, and E, folic acid, and thiamine in foods. Light also decrease the vitamin B_6 and riboflavin. Unsaturated fatty acids are unstable in the presence of air. Packaging of food material is an important measure to protect the foods from losses due to exposure to air and light.

v) Avoid wide changes in pH

pH is important because vitamin A and K and folic acid are unstable in an acidic environment, whereas, vitamin C, D, and K, pantothenic acid, riboflavin, and thiamine are unstable in an alkaline medium.

vi) Minimize trimming and peeling

Trimming and peeling should be kept to a minimum. The skin of fruits has valuable amounts of fibre and vitamin C. The outer leaves of vegetables are good sources of some vitamins and minerals.

vii) Careful handling of perishable foods

Removal of diseased, damaged and scratched fruits and vegetables during grading and post harvest treatment are highly useful in reducing the losses.

viii) Avoid the use of sodium bicarbonate to cooking water

Addition of sodium bicarbonate to hasten the cooking of dhal or to retain the colour of vegetables causes heavy loss of thiamin and vitamin C, hence should be avoided.

ix) Moisture content of food

For best storage and to prevent nutritional losses in food grains and oilseeds, these should be thoroughly cleaned, graded and dried to bring down the moisture content below 10 per cent.

x) Packaging

Packaging of foods particularly fruit and vegetables minimize physiological and biochemical changes. Packaging in modified atmospheric (MA) condition reduce the losses of vital nutrients during storage.

xi) Storage at low temperature

The loss of moisture is reduced by storing the vegetables in an atmosphere of high relative humidity at low temperature. Canned foods retain higher levels of vitamin C and thiamine if stored at low temperature. Roots and tubers can be stored at a temperature between 3 to 10^0C to keep sprouting minimum. Ageing of leafy and other vegetables, and fruits can be retarded by low temperature storage.

11.11 FOOD ANALYSIS, RESIDUE ANALYSIS

11.11.1 Food Analysis

Food analysis enables us to know the composition of fresh food and food products. A complete analysis of fruits and vegetable products includes determination of water content, protein, fat, nitrogen-free extract, fibre and ash. Each group is not made up exclusively of allied chemical substances, but rather of substances that happen to have one or more properties in common. The methods employed for the determination of these six constituents involves precipitation, colour comparison, or centrifuging or titration.

The water is determined by drying at $\leq 120^0$ C (depending on the commodity) in ovens for a certain period; the protein by calculation from the total nitrogen; total nitrogen by digestion (of sample), distillation and titration using some chemicals; the fat by ether extraction; the fibre by removal of all acid and alkali soluble constituents, and weighing the residue; the ash by incineration.

11.11.2 Residue Analysis

Residue analysis is concerned with the safety of food for human consumption. Whether applied to analysis of any kind of residue, all residue analysis has its ultimate aim; the capacity to identify food as safe or unsafe for human consumption. Residues analyses on food are undertaken for a very wide range of purposes. In the development of agrochemicals and veterinary drugs, for example, detailed studies on persistence of drugs in crops and/ or animal tissues post-treatment are required. In addition, studies on the metabolism of these chemicals require extensive residue analysis. For chemicals used in farming or occurring as contaminants from the environment and/ or industrial processes, residue analysis is undertaken as part of the monitoring programmes of regulatory agencies to ensure that residues, where they occur in foods, are at levels with respect to the established maximum residue limits (MRLs). In the case of prohibited substances, residue testing is designed to monitor compliance with the regulations. Generalized format for residue analysis is shown in Figure 11.1.

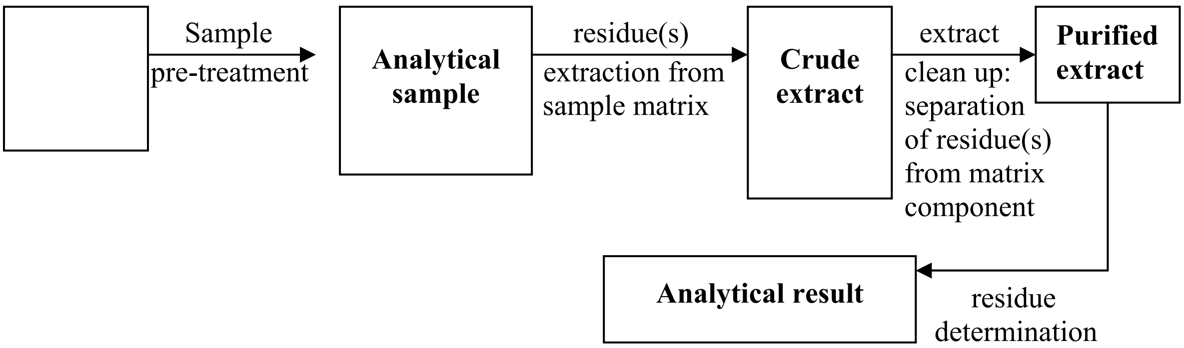

Figure 11.1: Generalized format for residue analysis

Within the spectrum of residue analysis methods, including screening, quantitative and confirmatory methods, there are methods ranging from single-step to multi-step methods. Example of the former are the four plate test for inhibitory substances in meat, for which all pre-determination steps are combined into a single step of cutting disc of frozen meat from the sample, placing them on prepared agar plates and incubating overnight, and a sol particle immunoassay (SPIA) test for sulphamethazine in urine, for which all pre-treatment steps are eliminated and the sample is applied directly to the test device. At other extreme are complicated methods with multiple steps such as methods for confirming the presence of residues of anabolic agents in tissues or bile. These methods involved weighing and homogenizing of sample, pH adjustment of the homogenate, overnight incubation with glucuronidase/ sulphatase to hydrolyse conjugates, extraction of residues directly with solvent or on a diatomaceous earth column, liquid/ liquid partitioning steps and multiple column chromatography or solid phase extraction (SPE) steps to remove co-eluting interferences, multiple evaporation of solvents, derivatisation of the residues and clean-up of the derivatised extracts, prior to determination by gas chromatography-mass spectrometry. In between these extremes lie the majority of residue methods but, in general, the extent of quantification and confirmation and the nature of the sample (solid or liquid) determine whether simple or more complex methods are used.

Table 11.1: Categories of chemical that can arise as residue in food

Category	Examples
a) *Natural*	
Normal components in food	Phytoestrogens, glycoalkaloids, erucic acid
Natural contaminants in food	Mycotoxins, phycotoxins (aquatic biotoxins)
b) *Synthetic*	
– Agricultural chemicals	– Pesticides, fertilizers
– Veterinary drugs	– Antibiotics, anthelmintics, growth promoters
– Food additives	– Preservatives, antioxidants
– Chemicals from packaging	– Vinyl monomers, oligomers
– Food processing chemicals	– Nitrosamines, polycyclic aromatic hydrocarbons (PAHs)
– Environmental contaminants	– Dioxins, polychlorinated biphenyls (PCBs)

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is malnutrition? What is the most common form of under-nutrition prevalent amongst vulnerable group?

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2. Discuss different methods that can reduce the nutrients losses.

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11.12 LET US SUM UP

Some foods contain toxic constituents, if consumed in sufficient quantities may prove to be hazardous. The hazardous substances include toxicants naturally occurring in foods, toxins produced by microorganisms, and environmental contaminants. The microorganisms most common to food are bacteria and fungi; get their entry in food as a result of unhygienic practices during food handling, processing and storage. Bacterial contamination is the most significant as it may result in food poisoning. Botulism is the most fatal and Staphylococcal food poisoning is the most common form of food poisoning due to bacterial contamination of food. Contamination can be reduced by safe food handling practices, processing under sanitary conditions, protecting food during storage, proper disposal of waste materials, and protection against contact with toxic substances. These practices will not only reduce the contamination from toxicants but also the nutritional losses and thus prevent food losses and nutritional deficiencies amongst population.

11.13 KEY WORDS

Aneamia	:	is a condition characterized by reduction in red blood cells, packed cell volume or circulating haemoglobin, resulting in pallor appearance and shortness of breath especially on exertion.
Contamination	:	entry of undesirable organisms in some material or object.
Endotoxins	:	toxins produced inside the cell wall and can only permeate the food or the body when the organism is killed.
Exotoxins	:	toxic substances produced by bacteria which diffuse out of the cells and stimulate the production of antibodies.
Malnutrition	:	is a condition result from an inadequate (under nutrition) or excessive intake of one or more nutrients (over nutrition) or some defect in metabolism, which prevents the body from using the nutrients properly, e.g., PEM, Vitamin A deficiency, obesity.
Pathogens	:	disease causing microorganisms.
Toxicity	:	is the capacity of a substance when tested by itself to harm living organisms.

11.14 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Foods contain some anti-nutritional factors.

   Excess consumption over a long period can cause health problems, e.g. lathyrism. See sub-sec. 11.2.

2. Protease inhibitor and solanine in potatoes, goitrogens, oxalic acid. See sub-sec. 11.2

3. Some bacteria produced toxins inside the cell wall.

   Unhygienic practices, cross contamination of food, contaminated water and containers, soil adhering to foods, insects, droppings of rodents, etc. See Sub-sec. 11.3.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Ingestion of contaminated food may result in food poisoning.

   Botulism, Staphylococcal food poisoning, Salmonellosis, Clostridium perfringens food poisoning, Cereus food poisoning, lathyrism. See sub-sec. 11.6 and 11.7.

2. Food may be contaminated by pathogenic organisms.

   Diseases caused by agents that enter the body through ingestion of contaminated food.

   Typhoid, cholera, salmonellosis, hepatitis, amoebiasis, etc. See sub-sec.11.6 and 11.7.

3. Moulds grow on agricultural products and produced toxic metabolites.

   Bacteria- Aspergillus flavus and Aspergillus parasiticus produce aflatoxins. See sub-sec. 11.5.

4. Residues in foods from fumigants, presence of metals beyond the permissible limits, chemical residues See sub-sec. 11.6.1.

Check Your Progress Exercise 3

Your answer should include the following points:

1. Undernutrition, over nutrition.

   PEM. See sub-sec. 11.10.

2. Parboiling, optimum heat treatment, save from exposure to oxygen and light, avoid wide changes in pH, careful handling of perishable foods, minimum trimming and peeling, storage at Low temperature. See sub-sec. 11.11.

11.15 SOME USEFUL BOOKS

1. Marriott Norman G. (1999) Principles of Food Sanitation (4th Edition), Aspen Publishers, Inc., Gaithersburg, Maryland.

2. Park, K. (1994) Textbook of Preventive and Social Medicine (14th Edition), Banarasi Das Bhanot Publishers, Jabalpur.

3. Ranganna, S. (1991) Handbook of Analysis and Quality Control for Fruit and Vegetable Products (2nd Edition), Tata McGraw-Hill Publishing Company Limited, New Delhi.

UNIT 12 QUALITY CHARACTERISTICS

Structure

12.0 OBJECTIVES

After reading this unit, you should be able to understand quality attributes:

- physical factors;
- appearance factors;
- textural factors;
- kinesthetic factors;
- chemical and microbiological characteristics;
- quality standards;
- quality evaluation;
- grading and certification; and
- adulteration of food- detection and prevention.

12.1 INTRODUCTION

Quality is combination of attributes, properties or characteristics that give a commodity value in term of human food. Quality is overall, consumer's satisfaction and value worth, which he is paying. It is necessary for the food industry to become quality conscious and move towards attaining the international quality standards. Following are the important component of quality.

1. Appearance
2. Texture or firmness
3. Flavour
4. Colour
5. Purity
6. Nutritional quality: Foods play a very significant role in human nutrition especially as source of carbohydrate, protein, fats, vitamins, minerals and dietary fibre.

Foods are often thought of as healthy and nutritive matter having no risk of food borne illness associated with their consumption. The probability of getting sick from eating raw or processed food should not exist. Preventing contamination of fresh and processed foods from human pathogens and dangerous levels of chemicals/pesticides residues is the best way to assure that foods are wholesome and safe for human consumption.

12.2 PHYSICAL FACTORS

The defects, disease and decay can impair quality of fresh horticultural commodities. Defects can originate before harvest as a result of damage by insects, diseases, birds and hail, chemical injuries, and various blemishes (scars, scabs, rusting, rind scrapping etc.). Post harvest defects include sprouting of potatoes, carrots, onions and garlic, rooting of onions and seed germination inside fruits such as tomatoes and peppers, presence of seed stems in cabbage and lettuce and floret opening in broccoli. Physical factors also include shrivelling and wilting, mechanical damage such as punctures, cuts, scratches, splits and crushing, skin abrasions, scuffing, deformation, compression, bruising, growth cracks in fruits and vegetables.

Temperature related defects (freezing, chilling, sunburn, sunscald) puffiness of tomatoes, blossom end rot of tomatoes, tip burn of lettuce, internal breakdown of stone fruits, water core of apples, black heart of potatoes are the physiological defects.

While most of these defects reduce post harvest quality of perishables. There are examples of defects that do not influence post harvest quality of fresh produce or which may be called as consumer-tolerable defects. These include healed frost damage, scars and scabs, healed insect stings, irregular shape, healed hail damage, sub-optimal colour uniformity, colour intensity variations etc. The presence of defects frequently lowers the grade of the produce, which are other wise of good quality.

Uncontrolled cold also will damage foods. If fruits and vegetables are allowed to freeze, they suffer discolouration, changes in texture, or cracked skins, leaving the food susceptible to attack by microorganism. Carefully controlled freezing on the other hand need not cause these defects. Fruits and vegetables after harvest, like other living systems, have optimum temperature requirements. When held 'at refrigeration temperatures of about 4°C, some are weakened or killed due to chill injury and deteriorative processes follow. The deterioration includes off-colour development, surface pitting, and various forms of decay. Bananas, lemons, squash, and tomatoes are examples of products that should be held at temperatures not lower than about 10°C for maximum quality retention

12.3 APPEARANCE FACTORS

The quality of a food may simply be judged from its appearance when it is placed in front of a consumer. For example, a slight turbidity or cloudiness in orange juice is acceptable but not in apple juice, which must be crystal clear. Thus the overall eye appeal of a product is more important than taste and odour, and may determine acceptance or rejection without a trial tasting. Appearance deserve much more considerations in determining quality of a food and it includes size (dimensions, weight, volume), shape (diameter, depth ratio, smoothness, compactness, uniformity), colour (uniformity, intensity), gloss (nature of surface wax) and different external and internal defects.

Physical factors are such as size, shape, freedom from defect/damaged surface, type and extent of damaged parts. The optical properties such as colour, gloss and transparency of fruits and vegetables and the consistency of the processed products are also appearance factors that are indicative of quality. The appearance factors are highly useful and practiced in quality evaluation of fruits and vegetables, as well as in processed products.

Colour increases the attractiveness of many fruits and vegetables and used as a maturity index as colour undergo many changes as a part of the ripening process. Unripe fruit is usually green and in many types of fruit, the green colour becomes lighter during ripening and maturation owing to breakdown of chlorophyll, for example in apples, grapes, papaya. This may reveal underlying yellow or red pigments. Peel and pulp often undergo different colour changes, as in apples and bananas, In some cases, fruit colour is a strong indicator of eating quality and shelf-life, for example, tomatoes and bananas. Size and shape of fruits and vegetables are of major interest to the grower as it is directly proportional to the yield and also very useful in grading and handling during processing and transportation.

Defects may be caused by: (a) deformities caused by unfavourable environmental conditions (b) insects and microorganisms (c) mechanical injury during handling, transportation and processing such as damage, bruising and crushing (d) specks and sediments (e) foreign material or any other harmful added substance.

12.4 TEXTUAL FACTORS

Texture include various factors such softness, hardness, firmness, juiciness, grittiness or chewiness, fibrousness, mealiness and stickiness felt by the consumer when he handles the food with fingers (hand feel) or with the tongue, teeth or palate (mouth feel). Any deviation from the expected texture is said to be a quality defect. The texture of foods changes due to aging, improper processing or storage. Fresh fruits and vegetables become soggy due to over-ripening. Texture is an important factor in deciding the consumer acceptance of a food. In fact, quality of a food is mainly judged by its freshness/ripeness/ maturity or proper processing. For example, crispness of potato chips, the firmness and crunchiness of apples, and juiciness of fruit such as melons, non-sticky are indicative of prime quality of the food.

12.5 KINESTHETIC FACTORS

These are the quality factors which are judged by hands feel, mouth feel, and judged by sense of touch and tells about, chewiness, softness, juiciness, fibrousness, grittiness, mealiness, stickiness of fresh and processed foods.

12.6 FLAVOUR FACTORS

Flavour is a complex of taste and aromatic components. Total flavour can rarely be assessed by the consumer prior to purchase but it is critical in the repeat purchase of a particular product or product cultivars. Key taste components in fresh produce are sweetness, acidity, astringency and bitterness. Sweetness of some fruit may increase dramatically during ripening due to conversions of starch into sugars, for example in apples, bananas, mangoes and pears. Aroma may be fragrant, acidic & burnt and can be determined to some extent before purchase by the consumer but it tends to be important as a positive factor only in highly aromatic products such as certain cultivars of melon or mangoes.

Evaluation of flavour factor is highly subjective and depends on the discriminating ability of the consumer as flavour includes the sense of smell as well as the sense of taste as experienced by a consumer. People differ in their sensitivity to different odours and tastes as much as in their preference for various types of foods. In addition, consumers are influenced to some extent on the appearance, colour and texture of the food while evaluating the flavour characteristics.

12.7 CHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS

12.7.1 Chemical Characteristics

Lipid oxidation and non-enzymatic browning are two major chemical characteristics which, affect the quality of fruits and vegetables during processing and storage and lead to a deterioration in sensory qualities.

Lipid oxidation results in production of off flavour as well as loss of ascorbic acid. It is influenced by light, oxygen concentration, high temperature, sunlight and the presence of iron and copper, and water activity. Control of these factors can significantly reduce the extent of lipid oxidation in foods.

Non-enzymic browning is one of the major causes of quality deterioration and takes place during frying, cooking, storage of dried and concentrated foods. The non enzymic browning is caused by the reaction of amino acids and reducing sugars through Mallard reaction, leading to insoluble black brown pigments which , produce bitter taste and loss in nutrients.

There is some loss of colour in fruits and vegetable during maturation, ripening, storage and processing due the degradation of chlorophyll, anthocyanins and carotenoids by oxidation. For example, dehydrated green peas and beans packed in clear glass containers undergo photo-oxidation and loss of desirable colour occur.

More than 150 reddish water-soluble anthocyanin pigments are present in the plant kingdom. Some anthocyanins form complexes with metals such as Al, Fe, Cu and Sn. by chemical reaction. These complexes generally result in a change in the colour of the pigment (for example, red sour cherries react with tin to from a purple complex) and are therefore undesirable. Since metal packaging materials such as cans could be sources of these metals, they are usually coated with special organic linings to avoid these undesirable reactions.

The carotenoids are a group of mainly lipid soluble compounds responsible for many of the yellow and red colours of food products. The main cause of carotenoids degradation in foods is oxidation. The mechanism of oxidation in processed foods is complex and depends on many factors. The pigments may auto-oxidise by reaction with atmospheric oxygen due to light, heat and the presence of pro-and anti-oxidants.

Ascorbic acid is the most important vitamin in fruits and vegetables and its stability vary markedly as a function of environmental conditions such as pH , concentration of trace metal ions and oxygen because it is oxidized in the presence of oxygen.

12.7.2 Microbiological Characteristics

The microbial action is associated with the presence of bacteria, yeasts and moulds on vegetables and fruits resulting in deterioration of quality during normal processes of aging. The microbial attack on fruits and vegetable and their processed products usually alter the appearance, texture, colour, odour, flavour or slime formation. The appearance includes colour changes, visible growth of microorganisms, formation of pockets of gas and microbial growth especially that of moulds on the surface of food products. As some foods deteriorate, they become soft or mushy. Degradation of foods results in the formation of compounds that have unacceptable odours and flavours.

The most common microbial spoilages in fruits and vegetables are mildew, brown rot, soft rot, black rot, green rot, mould rot or souring and water soaked musky areas, brown or white patches. These spoilage of quality are caused by *Penicillium italicum, Aspergillus niger, Alternaria sp., Mucor sp., Byssochlamys fulva, Botryis cinerea, Rhizopus nigricans, and saprophytic* bacteria.. Dry rots often lead to darkening and discolouring, and hardening of the surface of vegetables and fruits.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe quality.

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2. What are the quality characteristics of foods?

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3. List the main chemical characteristics.

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4. What are the main spoilage in fruits and vegetables?

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12.8 QUALITY STANDARDS

Different standards are employed to control the quality of fresh and processed foods in the country. Food standards for ensuring the quality and safety of foods for human consumption have been formulated and enforced by law in India. Food standards have been also prescribed based on the International Codex Alimentarius with suitable modification to suit Indian conditions. Different quality standards are summarized below.

Different Quality Standards

Name of standard	Features
a) Legal standards	– Mandatory standard established by federal state or municipal agencies. – Set up by law or represented by appropriate act. – Concerned with freedom from adulteration and proper quality control measures i.e. insects, moulds, yeasts, pesticides, maximum limit of preservative and food without contamination.
b) Company standards	– Established by food industry. – Represent consumers image and become trademark of symbol of product quality. – Are used by private firms or supermarkets.
c) Industry standard	– Established by an organised group for any given commodity. – Become effective by pressure from market organization or specific commodity group where legal standards are not involved.
d) Consumer or grade standards	– Represent consumer's requirement of a grade/standard product. – Based on experience in use by the industry for consumers.

The different standards take into consideration intrinsic qualities of foods, nutritional aspects, hygienic values and consumer appeal. Some standards are voluntary in nature and some are mandatory.

12.8.1 Legal Standards

These are also called as Health Ministry (Government of India) standards and are mandatory in nature. They are prescribed to ensure minimum quality in the foods marketed and promulgated under the Prevention of Food Adulteration Act other Rules and Orders of Government of India which cover food items: beverages, starchy foods, spices and condiments, sweetening agents, edible fats, milk and milk products, common salt, fruit products, edible oils, cereal products, vanaspati, vinegar, sweets and confectionary, food colours, limits for preservatives, antioxidants, emulsifying and stabilizing agents, flavouring agents, pesticide residues.

Quality denotes the degree of excellence of a product. It is indicated in terms of grades, standards and specifications which are laid down by a competent authority in the country. It is an important consideration in marketing of a product. Consumers are concerned about the safety, nutritional quality, aesthetic value, convenience to use and cost of foods. An established system of quality control assures uniformity in standards and thereby ensures that each food stuff is what it possess to be and what its label declares, if there is one.

12.8.2 Market Standards

The market dictates some quality parameters in the food stuffs marketed. There can be more than one quality requirement for a particular commodity. The economic status and quality consciousness of the consumer influences the market standards and they are voluntary in nature. Examples are different, grades of fruits, vegetables, rice with more or less broken, pulses etc.

12.8.3 Industry Standards

These standards require special quality factors in the foods the consumer purchase. Wheat miller requires wheat with high milling yield. A baker will require a wheat flour with high percentage of gluten of good strength to obtain a good loaf of bread. Similarly fruit processing industry will require certain specific qualities in the fruits like colour, flavour when they are purchased.

12.9 QUALITY EVALUATION

The quality evaluation of fruits, vegetables, other foods and processed products gives useful information on nutritional and biochemical characteristics. Quality evaluation methods can be destructive or non-destructive. They include both objective (based on instrument readings) such as physical, chemical, or microbiological and subjective (based on human judgment, using hedonic scales) methods as in taste. Subjective methods are also called as sensory analysis.

The physical, chemical and microbiological analytical methods are considered to be objective. These methods are usually standard scientific tests, which, one should be in a position to reproduce with the same results by any trained technician. Physical measurements include product attributes such as; size, weight, colour, texture, headspace and even impurities such as filth and insects. Chemical methods are usually more complex and often require sophisticated instrumentation. Precise tests for moisture, total soluble solids, titratable acidity, vitamins, colour pigments, proteins, carbohydrates, ash, pectin and fiber have become standard practice. Microbiological methods are used to determine the presence of bacteria, moulds and yeasts. The details of some of the methods used in the quality evaluation are given below:

12.9.1 Appearance Quality

Appearance quality of fruits and vegetables is measured by size, shape, colour, gloss and presence physical defects.

Size: Dimension-measured with sizing rings, calipers. Weight-correlation is generally good between size and weight.

Shape: Ratio of dimensions – such as diameter/depth ratio used as indices of shape in fruits.

Colour: Uniformity and intensity-important appearance qualities. Visual matching- colour charts to match and describe colours of fruits and vegetables. Light ref1ectance is measured by Hunter Lab Colour Meters and Agtron E5W spectrophotometer. Light transmission meters are used to determine internal colour and various disorders (water core of apples and black heart of potatoes). Lovibond tintometer is also used to judge the colour and it has universal acceptance. Determination of pigments (chlorophylls carotenoids, carotene, lycopene, xanthophylls), and flavonoids (anthocyanins) is done by colourimetric procedures.

Gloss (bloom, finish): measured using a Gloss-meter or by visual evaluation.

Presence of defects (external and internal): Evaluated using a scoring system of 1 to 5 (1 = no symptoms, 2 = slight, 3 = moderate, 4 = severe, and 5 = extreme). Which may be expanded to a 1 to 7 or 1 to 9 hedonic scale.

12.9.2 Textural Quality

Yielding quality (firmness, softness): Hand-held testers - determine penetration force using testers such as the Magness-Taylor Pressure Tester and the Effegi penetrometer. Laboratory testing-fruit firmness is determined by Instron Universal Testing machine or Texture Analyser or by measuring fruit deformation using a Deformation Taster.

Fibrousness and toughness: Measured on by Instron or Texture Testing System a Fibrometer.

Succulence and juiciness: Measurement of water and extractable juice contents are the indicators of succulence and juiciness.

Sensory textural: Evaluate grittiness, crispness, mealiness, chewiness and oiliness.

12.9.3 Flavour Quality

Sweetness: Sugars are determined by colourimeteric methods. For quick measurement of glucose in field, is done by enzyme coated strips. Total soluble solids contents are (sweetness) are measured using refractometers.

Sourness (acidity): pH of juice is determined by pH meter or pH indicator paper. Total titratable acidity is determined by titrating the extracted juice with alkali to pH 8.1.

Saltiness: Salt is determined by chemical method. Saltiness can be measured subjectively by sensory evaluation.

Astringency: Determined by taste testing or measuring tannin contents.

Bitterness: Determined by taste testing or measurement of the glyco-alkaloids.

Aroma (odour): Determined by sensory panels in combination with identification of volatile components.

Sensory evaluation: Human subjects – judge and measure combined sensory characteristics (sweetness, astringency, bitterness, overall flavour intensity) of a commodity.

12.9.4 Nutritional Value

Various analytical methods are available for determination of total carbohydrates, dietary fibre, proteins, amino acids, lipids, fatty acids, vitamins, and minerals in fruits and vegetables.

Eating Quality Factors: These include sweetness, sourness, astringency, bitterness, aroma and off-flavours. Objective analytical determination of critical components must be coupled with subjective evaluations by a taste panel to yield useful and meaningful information about flavour quality of fresh fruits and vegetables.

12.9.5 Non Destructive Methods

Acoustic and vibration tests: The sound of a fruit as it is tapped sharply with a finger knuckle can change during maturation and ripening and this method is used by consumers while purchasing fruits. Melons are trapped to judge whether they are ready to be harvested.

Electrical properties: Electrical properties of the fruit change with the soundness or maturity or spoilage or physical damage of the fruit. It has been found that the capacitance of deteriorated cell increased while resistance decreased and therefore the measurements could be used to determine the freshness or age of the fruit. At 500 Hertz the dielectric constant of green and ripe peaches was 550 and 150 respectively.

Nuclear magnetic resonance (NMR): NMR is being used to find the maturity & quality of fruits and it is also correlated well to sugar content of bananas & apples, and oil content in avocado. It has been used to detect bruises on apples, peaches, pears and onions, pits in olives and prunes and insect damage in pears.

Near Infrared Reflectance (NIR): It has been studied to measure the internal qualities like sugars, acidity, soluble solids, nitrogen & calcium in apples, peaches, pineapples, mango and pear. It is used to find the fruit firmness & their storability in cold stores.

Sonic techniques: Based on the generation of resonating frequency that can be used to calculate internal resistance (hardness).

12.9.6 Summary of Methods of Determining Quality

Subjective*	– Include sense organs – Based on opinion of investigators – Past training experience of individual's power or perception – Statistical Analysis required to get meaningful results
Objective**	– Based on scientific tests – No human perception is involved
a) Physical method	– Size, texture, colour, consistency, headspace, fill and drained weight, vacuum, container, symmetry, defects, viscosity

b) Chemical methods	– Enzyme, moisture, fibre, pH, acidity, protein, specific gravity, fat/oil, carbohydrate, ash, mineral, vitamins, sugars, tannins, alcohols
c) Microbiological methods	– Mold, insect fragments, insect, excreta, foreign material – Differentiation between cell types/tissue/ microorganisms – Determination of microbial count spoilage detection in the fresh and processed products, microorganisms causing spoilage/ fermentation

**Subjective:* The human eye is used to evaluate colour.

***Objective:* An instrument is used to provide a special colour value based on the amount of light reflected-off the commodity surface or the light reflected through the commodity. e.g. Lovibond tintometer.

12.10 GRADING AND CERTIFICATION

The fruits, vegetables and other foods are graded according to size, shape, weight, colour and visible defects to obtain uniform quality and fetch good price for the fruits. This is done by hand or machines. Automatic grading machines are available in which vibrating screens or screens with various sized slots are used to separate different types of product. *Density grading* is carried out by using different concentration of brine for fruits. Grading for colour is carried out by an electronic colour-sensing device. Manual grading done by hands and is usually necessary to avoid losses or to keep losses within reasonable limits.

To ensures quality and purity, Government of India, has established different agencies like AGMARK, Indian Standard Institute to make grades of foods, vegetables & fruits and they are affixing their marks (Agmark, ISI) on the products. The quality *of* product is determined with reference to the size, variety, weight, colour, moisture and, fats content and other factors. The act defines the quality of most of the agricultural raw and processed products commodities into various grades depending upon the degree of purity in each case. The grades incorporated are grades 1, 2, 3 and 4 or special, good, fair and ordinary. The physical and chemical characteristics of products are kept in mind while formulating the Agmark specifications.

Grading of commodities like ghee, butter, vegetable oils, *atta*, spices and honey is voluntary. On the other hand, grading of spices, basmati rice, essential oils, onions, potatoes etc. that are meant for export, is compulsory under AGMARK to ensure quality. The grading of agricultural commodities has three main purposes to: (i) to protect the producers and consumer from exploitation. By knowing the quality and grade of his produce, he is in better bargaining position against the trader. (ii) serve as a means of describing the quality of the commodities to be purchased *or* sold by the buyers and sellers in the country and abroad. Which avoids the need for physical checking and handling at many points. (iii) protect the consumer by ensuring the quality of products he purchases.

Under Indian Standard Specification fruits and vegetables have three grades, super, fancy and commercial.

Super: The fruits and vegetables under this grade shall be of similar variety characters, fresh, firm, i.e. not withered or wilted, tender, succulent, well shaped, fairly smooth clean and well coloured which means that the commodity has a uniform good colour characteristics of the variety over practically the entire surface, well developed, uniform in size, free from injuries and damage by scars, insects, diseases or mechanical or other means.

Fancy: The fruits and vegetables under this grade shall be of similar variety characters, fresh, firm, tender, succulent, well shaped, fairly smooth clean and well coloured. And are free from, injuries, damage by disease, insects, mechanical or other means.

Commercial: The fruits and vegetables under this grade shall consists which do not conform to the requirements of either super or fancy grade, but the quality is fit for use of human consumption.

12.10.1 Certification

The Bureau of Indian Standards, (BIS) Act, 1986, operates a product certification scheme, including Food and Agriculture. The certification allows the licensees to use the popular ISI Mark, which has become synonymous with Quality products for the Indian markets.

The BIS certification is voluntary, and aims at providing quality, safety and dependability to the customer. All BIS certifications are carried out on Indian Standards, which have been found amenable to product certification. Presence of certification mark known as Standard Mark on a product is an assurance of conformity to the specifications. The conformity is ensured by regular surveillance of the licensee's performance by surprise inspections and testing of samples, drawn both from the factory and the market.

The Govt. of India on considerations of public health & safety, and mass consumption has enforced mandatory certifications of 135 products through Orders issued under various Acts. While the Bureau grants licenses only on application however the enforcement of compulsory certification is done by the notified authorities and the Bureau maintains a close vigil on the quality of goods certified through its surveillance operations.

The broad area of food and agriculture under certification are: processed fruits and vegetable products, spices and condiments, bakery, confectionery and nutritious supplements, dairy products, drinks and carbonated beverages, fish and fisheries products, food additives, food analysis and nutrition, food hygiene, food microbiology, food grains, livestock feeds, oils and oilseeds, pesticides residue analysis.

12.11 ADULTERATION OF FOOD – DETECTION AND PREVENTION

Food is consumed should be pure provide energy and nutrition and as such it should be wholesome and not have deleterious substances. The food adulteration implies that food lack certain standard of quality or purity and, is a great menace to public health, posing serious threat to the society.

Food adulteration is defined as the process by which the quality or the nature of a food product is adversely affected through the addition of a foreign or an inferior substance and the removal of a vital element, such as fat from milks and the addition of water to it. Adulteration of food may endanger health due to either addition of a deleterious substance or removal of a vital component. Adulteration may be intentional or unintentional. The intentional adulteration is a willful act intended to increase the margin of profit while the incidental contamination is usually due to ignorance, negligence or lack of proper checking facilities. Adulteration of food stuffs is commonly practiced in India as the consumers like to get maximum quantity for as low a price as possible. When the price of the food product is higher than the price, which the consumer is prepared to pay, seller is compelled to supply a food product of inferior quality, thus adulteration done.

12.11.1 Types of Adulterants

i) Intentional adulterants	*Substances added to food are:* sand, marble chips, stones, mud, other filth, talc, chalk powder, water, mineral oil, harmful colours.
ii) Incidental adulterants	They are pesticide residues, tin from can, droppings of rodent's larvae in foods.

We are eating foods daily laced with some toxic pesticides. Even the rodents and insects introduce into the food a high degree of filth in the form of excreta, bodily secretions and microorganisms responsible for food spoilage as well as its intoxication. The incidental poisoning can be prevented by the following:

- Regular 'market basket' surveys to warn people of dangerous build-up of toxins in food.
- Stepping up the integrated pest management programme to educate farmers about the judicious use of pesticides. No spraying should be done a week before harvest.
- Promoting the control of pests using their natural predators.
- Preventing industries from dumping poisonous effluents.
- Considering health costs while deciding pesticide policy.
- Use of safer pesticides like synthetic pyrethroides or malathion.
- Thorough washing of foods to get rid of much of toxins.

12.11.2 Detection of Food Adulteration

Few important food adulterants and simple tests to detect adulteration of foods

Substance	Adulterant	Tests
1	2	3
Tur dal	*Lakh* dal or metanil	1. *Lakh dal is* irregular in shape and of lighter, colour than turdal 2. Add concentrated HCI to moisten dal. Yellow colour Will turn into magenta red if metanil yellow is present.

Dals	Kesari dal Clay, stones, gravels Lead chromate (yellow)	Add 50 ml of dilute HCI to dal and keep on simmering water for about 15 min. The development of pink colour indicates the presence of kesari dal. Visual examination detects these adulterants. Shake 5 g of dal with 5 ml of water and add a few drops of HCI. A pink colour shows the presence of colour.
Bajra	Fungus	Immerse in saline water, fungi will come on top
Wheat, bajra and other food grains	Ergot (a fungus containing a poisonous substance) Dhatura seeds	a) Longer size purple black grains in bajra show the presence of ergots. b) Put some grains in a glass containing 20% salt solution. Ergot floats over the surface, while sound grains settle down. Dhatura seeds resemble chilly seeds with blackish brown colour which can be separated out by close examination
Tea leaves	Exhausted tea or black or bengal gram dal husk with colour	a) Tea leaves sprinkled on wet filter paper would immediately release added colour b) Spread the little slaked lime on white porcelain tile or glass plate. Sprinkling a little tea dust on the lime will show the presence of coal tar dye. In the case of genuine tea, there will be only a slight greenish yellow colour due to chlorophyll which appears after sometime.
Mustard seeds	Argemone seeds	Agremone seeds have no round structure, they are pointed and are mere blackish than mustard seeds.
Chilli powder	Saw-dust and red colour	Sprinkle on the surface of water. Saw-dust floats. Added colour will colour the water.
Edible oils	Argemone oil Mineral oil	Add concentrated nitric acid to the sample and shake carefully. Red to reddish brown colour in acid layer would indicate the presence of argemone oil. Take 2 ml of edible oil and add equal quantity of N/2 alcoholic potash. Heat in boiling water bath for 15 min and add 10 ml of water. Any turbidity shows the presence of mineral oil.

	Castor oil	Dissolve some oil in petroleum ether in a test tube and cool in ice salt mixture. Presence of turbidity within 5 min indicates the presence of castor oil.
Turmeric	Coloured saw dust, metanil yellow Starch	Take a teaspoon full of turmeric powder in a test tube. Add a few drops of concentrated HCI. There is instant appearance of violet colour which disappears on dilution with water. If the metanil yellow colour persists (an artificial dye) the presence of non- permitted coal tar is indicated. Add iodine solution to turmeric solution, it will turn violet if starch is present.
Coriander	Horse dung powder	Soak in water. Horse dung will float which can be easily detected.
Ghee or Butter	Vanaspati Mashed potatoes, sweet potato and other starches.	Take about one teaspoonful of melted ghee or butter with equal quantity of concentrated HCI in a test tube and add to it a pinch of cane sugar. Shake well for one minute and observe it after 5 min. Appearance of crimson colour in lower (acidic) layer shows the presence of ‘vanaspati’. The presence of mashed potatoes and sweet potatoes in a sample of butter can easily be detected by adding a drop of tincture of iodine. The appearance of blue colour indicates the presence of mashed potato, sweet potato or other starches.
Black pepper	Dried seeds of papaya fruit Light berries	Papaya seeds can be separated out from pepper as they are shrunken, oval in shape and greenish brown or brownish black in colour. The suspected papaya seed in black pepper sample is distinguishable by its characteristic repulsive flavour quite distinct from the bite of black pepper. Light berries float on spirit.
Rice	Marble or other stones	Place a small quantity of rice on the palm of the hand and gradually immerse the same in water. The stone chips will sink.

Wheat flour (maida)	Atta from which maida suji has been extracted	When dough is prepared from resultant wheat flour, more water has to be used and chapattis prepared out of this will blow out. The normal taste of chapattis prepared out of wheat is somewhat sweetish whereas those prepared out of adulterated wheat flour will taste insipid.

12.11.3 Prevention of Food Adulteration

To safeguard the interest of the consumer, it is necessary to have a check and control over the quality of food marketed for human consumption.

In India "Prevention of Food Adulteration Act" was promulgated by the Government in 1954 and the Rules under this act were made in 1955. The act was intended to make provisions for the prevention of adulteration in food. The act empowers the government agencies to prevent this unsocial activity and safeguard the health of the people. The implementation of the Act/Rules is done at State/Union territory level whereas the Central Government may give such directions it may deem necessary regarding execution of the provisions in the Act/Rules. For this purpose, the 'Central Committee for Food Standards' was constituted with (a) members representing concerned ministries, (b) representatives of consumers, medical professionals, agricultural, commercial and industrial organizations and hotel industry, (c) representatives of State/Union territories and (d) Directors of the Central Food Laboratories and (e) Director General of Health Services. Four Central Food Laboratories and a number of state level laboratories were established for analysis of samples collected by the state level food inspectors.

Standards under PFA Act and Rules: The standards laid down under the PFA Act and Rules are minimum standards of purity and are based on the agricultural practices, climatic conditions prevailing, and economic conditions and nutritional status of the people in the country

The standards are mandatory in nature and by government laws food articles which do not conform to the standards are considered unfit for human consumption. The Act and Rules deal with preservatives, poisonous metals, naturally occurring toxic substances, anti-oxidants, emulsifying and stabilizing agents, flavouring agents, colouring matter and other food additives, insecticides and pesticides, solvent extracted oils and edible flours, non-alcoholic beverages, starchy foods, spices and condiments and their mixes, honey, jaggery, saccharin, coffee, tea and milk, milk products, edible oils, cereals, baked products, sweets and confectionary and a range of similar products. The Act and Rules deal with the administrative procedures to be followed for reporting, analysis, prosecution, presentation of cases in a court of law and punishment to be carried out.

The adulterated food articles are defined under the Act.

12.11.4 Prevention of Food Adulteration Tips to Consumer

Despite the advantages of modern technology, illness due to adulterated/ contaminated food is one of the leading causes of sickness or death. Food-borne diseases range from acute gastroenteritis to precancerous/cancerous stage. Consumers are therefore offered tips in ascertaining quality of food by quick and simple tests for detection of common adulterants in food.

- Read label before purchasing.
- Purchase food articles from licensed vendors and insist on Bill or Cash Memo.
- Prefer foods sold in packed containers even if the cost is higher.
- Prefer foods certified by Govt. agencies like Agmark, ISI certification mark and FPO
- Avoid coloured foods especially sweetmeats or sharbats or ice candy.
- Buy foods from reputed firms.
- Do not buy cut or exposed fruits or vegetables.
- Do not use containers or packages used for insecticide chemicals or non-edible items.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand about quality standard?

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2. How many types of adulterants are there and the Act to prevent adulteration?

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3. What is Agmark?

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4. What are the benefits of grading and certification?

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5. Name the method of quality evaluation?

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12.12 LET US SUM UP

Quality of food is a combination of attributes, properties or characteristics that give a commodity value in terms of human food. The important components of quality are: appearance, texture or firmness, flavour, colour, purity and nutritional quality. Food plays a very significant role in human nutrition especially as source of carbohydrate, protein, fats, vitamins, minerals and dietary fibre. Lipid oxidation and non-enzymatic browning in fruits and vegetable are two major chemical characteristics, which affect the quality of food during processing and storage. The microbiological characteristics are associated with the presence of bacteria, yeasts and moulds on foods resulting in deterioration of quality.

Different quality standards are formulated and enforced by Government of India to ensure food quality and safety for human consumption. The quality evaluation of fruits, vegetables, other foods and processed products gives useful information on nutritional and biochemical characteristics and can be determined by destructive or non-destructive methods. These include both objective such as physical, chemical, or microbiological methods and subjective such as taste. Food adulteration is defined as the process by which the quality or the nature of a food product is adversely affected through the addition of a foreign or an inferior substance and the removal of a vital element. Adulteration may be intentional or unintentional. In India "Prevention of Food Adulteration Act" was promulgated by the Government to make provisions for the prevention of adulteration in food by law.

The fruits, vegetables and other foods are graded according to size, shape, weight, colour and visible defects to obtain uniform quality which is done by hand or machines. Automatic grading machines are available. Grading for colour, an electronic colour-sensing device is used. To ensures quality and purity, Government of India, has established Agricultural Produce Grading and Marketing Act (Agmark), and Indian Standard Institute to make grades of foods, vegetables and fruits & they are affixing the Agmark & ISI quality mark respectively on the products. The Bureau of Indian Standards, (BIS) Act, operates a product certification scheme, including Food and Agriculture. The certification allows the licensees to use the ISI Mark, which insure quality of products. The BIS certification is voluntary, and aims at providing quality, safety and dependability to the customer. All BIS certifications are carried out on Indian Standards, which have been found amenable to product certification.

12.13 KEY WORDS

Quality	:	It is a measure of the degree of excellence or degree of acceptability by the consumer.
Appearance	:	It include size, shape, colour, gloss and other visible defects of foods.
Texture	:	It include softness, hardness, firmness, juiceness, chewness, mealiness & stickiness, of the food commodity.
Flavour	:	It is a complex of taste and aroma.
Chemical characteristics	:	The lipid oxidation and non enzymatic browning are the chemical reactions of the rancidity and browning of foods respectively.
Microbiological characteristics	:	The microbiological characteristics are associated with the presence of bacteria, yeasts and moulds on foods resulting in deterioration of quality attributes
Quality standards	:	They are something that is set up and established by the authority for measuring quality.
Quality evaluation	:	The quality evaluation gives information on nutritional and biochemical characteristics of foods and determined by destructive or non-

destructive methods which can be objective or subjective.

Adulteration : Food adulteration is the process by which the quality or the nature of a food product is adversely affected by the addition of a foreign or an inferior substance.

Grading : The food products are graded according to size, shape, weight, colour and visible defects to obtain uniform quality.

Certification : The certification allows the licensees to use the quality Mark to insure quality of products and certification may be voluntary or mandatory.

Hygiene : It involves all measures to ensure the safety, soundness and wholesomeness of food at all stages of production and processing.

12.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Quality is combination of attributes, properties or characteristics that give a commodity value in term of human food.
   - Quality is overall, consumer's satisfaction and value worth.
   - Appearance, firmness, flavour, colour, purity, nutritional quality:
2. Your answer should include the following points:
   - Physical characteristics.
   - Chemical characteristics.
   - Nutritional characteristics.
3. Your answer should include the following points:
   - Lipid of oxidation.
   - Non-enzymatic browning.
   - Rancidity.
   - Maillard reaction.
4. Your answer should include the following points:
   - Mildew
   - Brown rot
   - Soft rot
   - Black rot
   - Green rot
   - Mould rot
   - Souring

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - Different standards for ensuring the quality and safety of foods for human consumption have been formulated and enforced by law in India.
   - Legal standards.
   - Company standards.
   - Industry standards.
   - Consumer or grade standards.
2. Your answer should include the following points:
   - Intentional adulterants.
   - Incidental adulterants.
   - Prevention of Food Adulteration Act 1955.
3. Your answer should include the following points:
   - Derivative of Agricultural Marketing.
   - Agricultural Produce Act, 1937.
   - AGMARK products are free from adulteration.
4. Your answer should include the following points:
   - Uniform quality and fetch good price.
   - The grades are1, 2, 3, & 4.
   - Special, good, fair and ordinary grades.
   - Super, fancy & commercially grades.
   - BIS Act.
   - ISI mark.
5. Your answer should include the following points:
   - Physical, Chemical and Microbiological methods.
   - Objective and subjective methods.
   - Non-destructive methods.

12.15 SOME USEFUL BOOKS

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6. Verma, L.R. and Joshi. V.K. (2000) Post-harvest Technology of fruits and vegetables. Indus Publishing Company, New Delhi.

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UNIT 13 DETERIORATIVE FACTORS AND THEIR CONTROL

Structure

13.0 OBJECTIVES

After reading this unit, you should be able to:

- know shelf life and dating of food;
- explain causes of food deterioration;
- know nutritional changes in food;
- describe food borne diseases;
- know food allergies and anti-microbial agents used in food;
- explain enzyme inactivation;
- describe different treatments to keep the food safe; and
- know hygiene and sanitation.

13.1 INTRODUCTION

Deterioration of food can be defined as any decay due to physical or chemical means or undesirable decomposition of constituents by excessive growth of microorganism. Food deterioration is manifested by the reduction in aroma, flavour, textural and nutritional values of foods. In extreme cases, the foods become totally unpalatable and is unfit for human consumption. Some microorganisms are also known to release toxins that may cause damage to health.

13.2 SHELF LIFE AND DATING OF FOODS

All foods have a time of the usefulness i.e. a time limit during which they can be consumed. Shelf life is the time required for a food product to reach to an unacceptable quality. The length of the shelf life of foods will depend on the type of food, processing method, packaging, and storage conditions. It is a practice to add some form of dating system to retail packages of foods so that consumers may have some indication of the shelf life or freshness of the products they buy. Food manufacturers put code dated on their products. The dates of manufacture ("pack date"). The date the product was displayed ("display date"), the date by which the product should be sold ("sell by date"), the last date of maximal quality ("best used by date"), and the date beyond which the product is no longer acceptable ("use by date" or expiry date").

One recent system for monitoring shelf life uses labels or tags on foods that respond to a combination of time and temperature to which the product has been exposed. These are called "time-temperature" indicators and are based on the principle that both time and temperature are important in the spoilage of foods.

13.3 CAUSES OF FOOD DETERIORATION

The major factors affecting food deterioration are: (1) growth and activities of microorganisms, principally bacteria, yeast, and moulds; (2) activities of food enzymes and other chemical reactions within food itself; (3) infestation by insects, parasites, and rodents; (4) inappropriate temperatures; (5) gain or loss of moisture; (6) oxygen (7) light (8) physical stress and (9) time.

These factors can be divided into biological, chemical and physical factors and often they do not operate in isolation. Bacteria, insects, and light, for example, can all be operating simultaneously to spoil food in the field or in a warehouse. Similarly, heat, moisture, and air simultaneously affect the multiplication and activities of bacteria and chemical activities of food enzymes. At any time, many forms of deterioration may take place, depending on the food and environmental conditions. The major types of spoilage of foods are microbiological, biochemical, physical and chemical.

13.3.1 Chemical Reactions

Chemical reactions take place in the presence of atmospheric oxygen and sunlight. Two major chemical changes, which occur during the processing, and storage of fruits and vegetables are lipid oxidation and non-enzymatic browning which deteriorate sensory quality, colour and flavour.

Lipid oxidation is influenced by light, local oxygen concentration, high temperature and the presence of iron and copper, and water activity. Control of these factors can significantly reduce the extent of lipid oxidation or rancidity in foods.

Non-enzymatic browning is one of the major causes of deterioration which takes place during frying, cooking, storage of dried and concentrated foods through Maillard reaction between reducing sugars and amino acids present in the foods and formed black brown insoluble pigments.

13.3.2 Biochemical Reactions

Different biochemical reactions in foods and plants tissues are catalysed by enzymes. They are responsible for certain undesirable or desirable changes in fruits, vegetables and other foods. Examples involving endogenous enzymes include: (a) the post-harvest senescence and spoilage of fruit and vegetables; (b) oxidation of phenols in plant tissues by phenolases leading to enzymic browning; (c) sugar – starch conversion in plant tissues by amylases; (d) post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

Factors responsible for controlling enzymatic activities are: temperature, water activity, pH, chemicals which can inhibit or enhance enzyme activity.

Enzymatic spoilage is the greatest cause of food deterioration. If enzymatic reactions are uncontrolled, the off-odours, and off-colours may develop in foods. In fruit and vegetables, enzyme-induced oxidative breakdown of unsaturated fatty acids occurs extensively which, give characteristic aromas during ripening of fruits. Enzymatic browning take place in apples and potatoes during cutting and peeling and exposed to air, due to the oxidation of phenols by peroxidase and polyphenoloxidase.

Certain changes are produced by enzymes of foods and micro-organisms that contaminate the food. Ripening of banana is due to the enzymes present but after some time the fruit becomes too soft by microorganism enzymes and become unfit to eat. Enzymes convert starch into sugars, proteins into amino acids, and pectin into pectic acids and this change the constituents of food. Enzymes can act between 0^0 and 60^0C but 37^0C is optimum temperature. All enzymes are inactivated at 80^0C.

13.3.3 Physico – Chemical Reaction

Physico-chemical reactions are caused by freezing, burning, drying and bruising of fruits and vegetables during storage, handling and transportation, which result in food deteriorations.

Food processing or storage causes some deterioration in colour of fruits and vegetables due to the degradation of the chlorophyll resulting dull olive-brown colour. Dehydrated green peas and beans packed in glass containers undergo photo-oxidation and loss of desirable colour.

In addition to chlorophyll, anthocyanins and carotenoids also give colour to fresh and processed foods. Anthocyanins form complexes with metals which results in change in the colour of the pigment. Red sour cherries react with tin and form undesirable purple complex. Carotenoid degradation occurs in foods by oxidation in the presence oxygen, light and heat.

One major undesirable physical change in dried food powders is the absorption of moisture, which results in caking. In general, moisture absorption is associated with increased cohesiveness. Caking does not occur at water activities of less than about 0.4 at ambient temperature.

13.3.4 Microorganism: General Principles, Causes and Growth

Most significant deteriorative changes occur in foods due to microorganisms present in air, soil, water, on fruits, vegetables and foods. They are so small that they can only be seen through microscope. There are three types of microorganisms which cause spoilage: (1) Bacteria, (2) Yeasts (3) Moulds.

Bacteria

Bacteria are minute unicellular microorganisms. The growth of bacteria depends upon food , temperature, pH, moisture and oxygen. Bacteria are much more difficult to kill and are the most common causes of food spoilage. They are present in active form (vegetative stage) or resting form (spore stage). In vegetative stage, bacteria are destroyed at boiling temperature but spores require application of heat (100^0C) for a long time (six hours) or 30 min at 121^0C under 10 lbs pressure.

All forms of bacteria are sensitive to acids and can be killed easily in acidic pH at a temperature of boiling water. So foods with high acid content (all fruits, tomatoes, pickles etc.) are processed at 100^0C whereas low acid foods such as corn, peas, beans and all vegetables except tomatoes have to be processed at higher temperature (116^0C) in a steam pressure to kill bacteria. The temperature maintained and the length of time, the food is held vary with kind of foods. Moist heat resistant bacteria are present in the soil, hence, preparation and processing of root vegetables require special care. *Clostridium botulinum* causes spoilage in canned foods.

Bacteria enter through stomata and lenticels. The most common bacteria causing significant reductions in shelf life of fruits and vegetables is the soft rotting species of the genus *Erwinia*. Under suitable conditions they produce large quantities of extracellular enzymes which rapidly macerate the tissue which gives unpleasant off-odours

Most of the pathogens of fruits and vegetables will grow between 6 and 35^0C. Some (*B. cinerea)* will survive and even grow at low temperatures, 1^0C, on agricultural produce, whereas *Botryodiplodia theobromae* or *Aspergillus niger* cause losses in warm regions.

Each kind of bacteria has a definite range of food requirements. Level of moisture in food is important in preventing or allowing the bacterial growth in the food. Bacteria require more moisture than yeasts or moulds. Each bacteria has an optimal temperature at which it grows best. Temperature below and above the optimum adversely affects the growth of bacteria. pH determines the kind of bacteria that well grow on the food. Most bacteria grow best at neutral, pH, however, some bacteria also grow in acid or alkaline media.

On the basis of respiration bacteria are classified as:

- **Aerobic** : They require free oxygen for growth.
- **Anaerobic** : Do not require free oxygen for growth.
- **Facultative** : Grow either with or without free oxygen.

Yeasts

Fungi usually known as yeast are microscopic unicellular organisms, which are non-motile round or oval. Yeasts reproduce or multiply by a process of "budding". The bud when fully mature, breaks away from the mother cell and becomes independent and repeats the process of multiplication. Yeasts require less moisture and acidic pH to grow and do not grow in alkaline medium. Yeasts grow under moderate temperature (25-30 C) in solution containing sugar. Most of the yeasts usually do not grow in media containing more than 65% of sugar or 0.5% acetic acid. Heating at 60 ^{0}C for a few minutes is sufficient to destroy most species of yeasts. Boiling destroys yeast cells and spores effectively. Some yeast grow well in light sugar solution and acidic medium. Some yeasts are very useful in making bread, beer, wine, vinegar and many other fermented products. Yeasts are responsible for fermentation of fruits and fruit products. Yeasts are undesirable when they grow on fruits, juices, squashes, *sharbat*, honey etc. They spoil the appearance, taste, texture and wholesomeness of fruits and fruit products. During active fermentation, yeast can be recognized by formation of bubbles or foam on the surface of the product. Some of yeasts which grow on fruits are *Saccharomyces, Candida,* etc.

Moulds

Moulds are larger and more complex in structure than bacteria or yeast. Moulds are made up of mycelium and spores. They grow in a network of hair like fibres called mycelia and send up fruiting bodies that yield spores. A piece of orange left for a time becomes covered with a whitish or grayish cottony matter

They thrive best in closed, damp and dark situation and require adequate supply of warmth, moisture and air for growth. They are aerobic in nature and require less available moisture and can grow well at 25-30 C. Moulds prefer sugar containing substances like jam, jelly, preserves and other sweet based products. They can grow at wide range of pH (2 to 8.5) but majority grow well at acidic pH. Therefore, they grow nicely on pickles, juices etc. They can grow on many kind of foods especially when temperature, air and humidity are favourable. Their growth can be seen only on the surface of food. They not only consume nutrients present in food thereby lowering the food value but also produce odd by-products, which spoil the flavour, taste and texture of food hence change the quality contents of the entire products.

Majority of moulds are sensitive to heat and are destroyed at 60 C when heated for 30 minutes. Boiling quickly destroys both moulds and their spores. Some of common moulds are *Aspergillus Penicillium*, *Rhizopus* and *Heliminthosporium*.

Insect and Pests, Rodents

The main categories of foods subjects to insects and pest attack are fruits, vegetables, grains and their processed products, and dried fruits. The presence of insects and pests and their excreta in foods may render products consumable loss, in nutritional quality, production of off-flavours and acceleration of decay processes due to creation of higher temperatures and moisture levels and release of enzymes. The products of insect and pests activities such as webbing, clumped-together food particles and holes can also reduce the food values.

Warm humid environment promote insect growth, although most insects will not breed if the temperature exceeds about 35 C^0 or falls below 10 C^0. Many insects cannot reproduce satisfactorily unless the moisture content of their food is greater than 11%.

Rats and mice carry disease-producing organisms on their feet and/or in their feces and are known to harbour *Salmonella* associated with food-borne disease in humans. Rodents contaminate the food through defecation, urination or when walk over food or food contact surfaces. These animals also destroy intensively human's foods. Rats and mice gnaw to reach sources of food and drink and to keep their teeth short. Their incisor teeth are so strong that rats have been known to gnaw through lead pipes and unhardened concrete, as well as sacks, wood and flexible packaging materials.

13.4 NUTRITIONAL CHANGES IN FOOD QUALITY

The four major factors, which bring nutritional changes in food quality, are light, oxygen, temperature and water activity. However, because of the diverse nature of the various nutrients as well as the chemical heterogeneity within each class of compounds and the complex interactions of the above variables, generalizations about nutrient degradation can not be made.

The major nutritional changes which occurred in foods are due to microbiological, enzymatic and chemical reactions.

Microbiological

- Growth or presence of toxicogenic and/or infective microorganisms.
- Growth of spoilage microorganism.

Enzymatic

- Hydrolytic reactions catalyzed by lipases, proteases, etc.
- Lipoxygenase activity.
- Enzymatic browning.

Chemical

- Oxidative rancidity.
- Oxidative and reductive discolouration.
- Non-enzymatic browning.
- Nutrient losses.

Physical

- Mass transfer, movement of low molecular weight components.
- Loss of crisp texture.
- Loss of flavours.
- Freeze-induced damaged.

One of the principal responsibilities of the food scientist is to preserve nutrients through all phases of food acquisition, processing, storage, and preparation. The key to doing this is a knowledge of the stability of nutrients under different conditions. Vitamin A is highly sensitive (i.e., unstable) to acid, air, light, and heat; on the other hand, vitamin C is stable in acid but is sensitive to alkalinity, air, light, and heat. Because of the instability of nutrients under various conditions and their water solubility, cooking losses of some essential nutrients may be greater than 75%. In modern food processing operations, however, losses seldom exceed 25%.

13.5 FOOD-BORNE DISEASE

Food-borne diseases cause food deterioration that may or may not alter a food's organoleptic properties but cause illness and disease to human beings after consumption. Food-borne diseases are classified as food infections or food intoxications. Food infections involve microorganisms present in the food at the time of consumption which then grow in the host and cause illness and disease. Food intoxications involve toxic substances produced in foods by microorganisms prior to consumption and cause disease upon ingestion. The toxin producer microorganisms need not to grow in the host to produce a disease or even be present in the food.

Staphylococcus aureus and *Clostridium botulinum* produce bacterial food poisoning by intoxication through the production of specific bacterial toxins. The toxin produced by *C. botulinum* is one of the most potent toxic substances known. Many bacteria can transmit food-borne infections capable of causing human disease. These include *Clostridium perfringens*, numerous members of the genus *Salmonella*, *Shigella dysenteriae, Vibrio parahaemolyticus, Streptococcus pyogens, Bacillus cereus, Campylobacter jejuni,* and other. A number of viral infection may also be contracted by man through contaminated food that has not been adequately processed or handled, including infectious hepatitis, poliomyelitis, and various respiratory and intestinal disorders. Over the last decade or so, several bacteria that had not been thought to be transmitted by food and cause human disease have found to do just that. Chief among these "newer" pathogens are *Aeromonas hydrophila*, *Yersinia enterocolitica*, *Listeria monocytogenes*, *Vibrio parahaemolyticus* and a particular type of *Escherichia coli* called 0157: H7 of particular importance is the recent discovery that some food-borne pathogenic bacteria can multiply at temperatures as low as 3.3^{0}C. This means that temperatures, which have been considered good for refrigerated storage, may not always keep food becoming a hazard.

Certain moulds produce mycotoxins, the best known being the aflatoxins by *Aspergillus flavus.* Aflatoxins are toxic to man and domestic animals. However, their carcinogenic properties are cause for much concern since aflatoxins can be produced in a wide range of cereals, legumes, nuts, and other products allowed to become mouldy. When such products occur in feeds, aflatoxins may subsequently be detected in the milk products of animals consuming the feed that is ultimately consumed by humans.

13.6 FOOD ALLERGIES

Food allergy may be defined as normal tissue reaction that may occur in some individuals after consuming a particular food or group of foods. Food allergens consists mostly of proteins, though some other chemical compounds present in foods may also produce allergic reaction.

Since the allergen is carried through all parts of the body, the allergies manifestations are many and varied. The skin and mucous membranes are particularly sensitive to the allergen. The sign and symptoms of allergy may include (i) Skin lesions, rash and eczema; (ii) Nausea, vomiting, diarrhoea and colitis; (iii) Headache, cold and asthma, and (iv) Redness, swelling, burning and itching of the eyes and irritation of the nasal mucous membrane. The allergy associated with consumption of orange and tomato juices is apparently due to traces of proteins present in the juice or to the peel oil.

The allergies are treated by drugs and also different types of diets are used in treatment of allergy (i) Synthetic diets, (ii) Elimination diets, and (iii) Restricted diets. Desensitization of the subject to the allergic food may also be carried out. Currently the only way to treat food allergies is to avoid the food that triggers allergic reactions.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is shelf-life and dating of foods?

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2. Name the major causes of deterioration.

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3. What are nutritional changes in the food quality?

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4. Name the bacterial causal organism of food- borne infections.

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13.7 ANTI-MICROBIAL AGENTS USED IN FOOD

Anti-microbial agents are the chemicals which inhibit the growth & development of bacteria, moulds and yeasts. They are weak acids work in the un-ionized form. They are not effective above their pKa values.

The use of anti-microbial agents depend on; **a**nti-microbial activity, pH of the food product, food composition, processing, and storage conditions, solubility, flavor, cost, marketing impact. The details of the most commonly used anti-microbial agents in food preservations are as follow:

13.7.1 Sulphite and Sulphur Dioxide

Sulphur dioxide and its derivatives have been extensively used in foods as a food preservative and anti-microbial agents. They act as an antioxidant, reducing & anti-microbial agents and prevents enzymatic, non-enzymatic reactions and microbial growth respectively. The common used forms are sulphur dioxide and sodium, potassium and calcium salts of sulphite, bisulfite or metabisulphite. The preservative action of sulphur dioxide as an anti-microbial agent in acid media, is due to undissociated compounds. It is like a biocidal and biostatic agent and is more active against bacteria than moulds and yeasts. It is more effective against Gram-negative bacteria.

13.7.2 Nitrite and Nitrate Salts

Nitrates and nitrites salts are inhibitors of toxic bacteria, involved in botulism, and considered as legal preservatives. Under regulations nitrites and nitrates are permitted as preservatives in cured meat and meat products including poultry at levels below 200 ppm. They also stabilize the colour after cooking and impart good flavour of lean meat without this the meat would be greeny brown. The use of nitrates and nitrites in the food industry is now subject to strict control.

13.7.3 Glycerol Esters

Glycerol esters show anti-microbial activity against Gram positive bacteria and yeasts. It is used as surface decontamination agents. It also inhibit *Clostridium botulinum* and widely applied in cured meats and refrigerated packaged fresh fish.

The inhibitory effect of the glyceride is due to the conduction of protons through the cell membrane, which effectively destroys the proton motive force that is needed for substrate transport. Death of cell arises due to the generation of holes in cell membranes.

13.7.4 Epoxides

Epoxides destroy all form of microorganisms, including spores and even viruses, but the mechanism of epoxides is poorly understood. They find applications in treating low moisture foods and to sterilize aseptic packaging materials. They are used in vapour state and after adequate exposure, most of residual unreacted epoxide is removed by flushing and evacuation.

13.7.5 p-Hydroxy Benzoate Alkyl Esters

The p-Hydroxy Benzoate Alkyl Esters (parabens) are widely used as anti-microbial agents in foods and pharmaceutical products particularly in baked foods, soft drinks, olives, pickles, jams and jellies and syrup. They are effective inhibitor of moulds and yeasts (0.5-0.1 %) but ineffective against bacteria, especially gram negative bacteria. In contrast to other *antimycotic* agents, the parabens are active at pH 7.0, and higher as they remain undissociated at these values.

Benzoates, sorbates, hydrogenperoxides, and propionates can also be used as anti-microbial agents.

13.8 ENZYME INACTIVATION

Some enzymes catalyze or initiate undesirable changes in colour, texture, flavour and nutrients of fruits and vegetables during storage and processing (Table 13.1). Inactivations of these enzymes prevent discoloration, improve flavour, soften tissues and loss of nutrients. Inactivation of enzymes is mainly done by blanching. Blanching is a mild treatment which expose plant tissues to steam or hot water, heating at 75-95 C for about 1 to 10 minutes, depending on the product requirements. At high temperature enzymatic proteins are denatured and make the enzymes inactive. If food processors did not blanch vegetables prior to freezing or dehydration, the natural enzymes would remain active even during frozen storage and destroy the product quality with time. Many vegetables which are not properly blanched develop a very noticeable off-odour and off-flavour.

Table 13.1: Enzymes responsible for quality deterioration in fruits and vegetables

Off-flavour development	• Lipoxygenase • Lipase • Protease
Texture changes	• Pectic enzymes • Cellulase
Colour changes	• Polyphenol oxidase • Chlorophyllase • Peroxidase (lesser extent) • Lipoxygenase*
Nutritional changes	• Ascorbic acid oxidase • Thiaminase

*hydroperoxides and radicals formed by lipid oxidation may destroy chlorophyll and carotenoids

In order to prevent undesirable changes in fruit texture, colour and flavour chemicals are used to inactivate enzymes as antioxidants. The inactivation of peroxidase is an indicator of effectiveness of blanching, and one could assume that all quality affecting enzymes had been destroyed.

13.9 TREATMENTS

The different treatments to prevent deterioration or spoilage of food should be performed so that it can be stored or preserved in fit conditions for future use. The classification of treatments of reducing deterioration is difficult because they do not act in isolation but take place together or one after the other. However the preservation procedures have two main characteristics:

- some of them are applied only to one or some categories of foods; others can be used across the board and thus a wider application (cold storage, freezing, drying/dehydration, sterilization, etc.);
- some guarantee food preservation on their own while others require combination with other procedures, either as principal or as auxiliary processes in order to assure preservation (for example smoking has to be preceded by salting).

13.9.1 Physical

It is better if the following physical treatments are kept in mind to control the spoilage.

- Heating,
- Cooling,
- Lowering of water content,
- Drying/dehydration,
- Concentration,
- Irradiation,

- Other physical means (high pressure, vacuum, inert gases),
- Salting.

13.9.2 Thermal

Heat or thermal processing includes heating and cooking, required to eliminate the potential of food borne illness. The simple act of cooking, frying, boiling or simply heating food prior to consumption are forms of food preservation. Cooked food itself can be held for several days provided it is protected from recontamination. Various methods in thermal processing include blanching, pasteurization and sterilization.

Blanching: Dipping of fruits & vegetables in boiling water or steam at temperatures around 75-95^{0}C for about 1 to 10 min, depending on the product requirements to inactivate enzymatic and biological activities. It is a necessary pre-treatment to achieve satisfactory quality in dehydrated, canned and frozen products. The process is required for reduction in enzyme activity otherwise undesirable changes in odour, flavour, colour, texture and nutritive value will occur during storage. It also helps in removal of intercellular gases to reduce the oxidative changes in food. Blanching may also result in some reduction in the microbial load and the texture may be improved.

Pasteurization: The food is heated to a temperature around 60 to 80 ^{0}C depending upon food product. The normal range is 65-75 ^{0}C at which nearly all the enzymes and vegetative microorganisms are inactivated. The heating may be done by steam, hot water, dry heat or electric currents, and then products are cooled promptly. Pasteurization does not kill all the microorganisms present in fruit juices. Some spores and spore forming bacteria like *Bacillus subtilis* can survive and multiply later.

Sterilization: Sterilization involves the use of heat at a temperature of 121°C (wet heat) for 15 min or longer to ensure total destruction of microorganisms including spores. The sterilized food must be placed in a container to prevent the entry of spoilage organisms. This is generally done with steam under pressure, as in a autoclave or commercial retort. Commercial pressure retorts operate at temperatures and for time intervals adequate to destroy large numbers of highly resistant bacterial spores within the canned food. Sterilization is not always necessary to kill all microorganisms but may be employed to destroy disease-producing organisms in the food.

13.9.3 Chemicals

Many chemicals will kill or inhibit the growth of specific microorganisms and prevent the deterioration of foods, but most of these are not permitted. A few that are permitted, in prescribed low levels in certain foods, include sodium chloride, acetic acid, sodium benzoate, sorbic acid, sodium, and calcium propionate, ethyl formate, and sulfur dioxide.

Sodium chloride: Common salt used in high concentration (15-20%) prevents the growth of microorganisms and increase the keeping quality of foods such as pickles. Salt at high concentration dehydrates microbial cells. Salt inhibits enzymatic browning and also acts as an antioxidant. Salt ionizes to yield chloride ions which, are harmful to the organisms and it also sensitizes the cell against carbon dioxide. Effectiveness of salt varies with its concentration and temperature.

Acetic acid: Acidic pH inhibits the growth of many microorganisms. Vinegar or acetic acid has germicidal and antiseptic properties and also checks aerobic and anaerobic fermentation. It is more effective against yeast and bacteria than molds. About 2% acetic acid prevents the spoilage of most products. It is used in preservation of pickles, sauces and chutney.

Citric acid: It is used in preservation of certain fruits and vegetables. It is added to jams, jellies, preserves and squashes. It increases the acidity and prevents mould growth.

Propionates: Sodium or calcium propionate is used most extensively in the prevention of mould growth. These are effective against moulds with little or no inhibition of most yeast and bacteria. Their effectiveness decreases with an increase in pH and optimal pH is 5 to 6, depending upon the food item. These are ideal preservatives for bread and baked foods to prevent contamination of loaves during slicing and/or wrapping.

Benzoic acid and its salt: Sodium benzoate as a salt of benzoic acid is used because it is more soluble than acid. It is benzoic acid molecule, which is germicidal. It is more effective against yeasts than molds. 0.06-0.10% of sodium benzoate preserves most fruit products (pH 3.5-4.0). In the long run, the benzoate may darken the products therefore, it is mostly used in coloured products of tomato, plum, watermelon, *jamun,* pomegranate and coloured grapes.

Sulphurous acid and its salts: Mostly potassium or sodium metabisulphite is used and gives characteristic sulpher dioxide smell. Sulphur dioxide retards oxidation, prevents discolouration or loss of flavour and vitamin C. It acts as a better preservative against bacterial fermentation and molds. It prevents enzymatic darkening of cut and peeled fruits and vegetables. But it cannot be used in products stored in tin cans because it causes pin holes in metals and forms incrustation of tin sulphide.

In dehydration of fruits and vegetables, burning of sulphur at levels 1000-3000 ppm preserves colour, as well as vitamin C, repels insects and destroys organisms. It bleaches colour of pigments and its use is restricted to products of fruit like mango, litchi, lime, orange, lemon, guava, etc.

Sorbic acid: It is an organic acid having anti-microbial properties and prevents moulds in preserves. The effectiveness of sorbic acid increases in acid media ($pH < 6.0$) and inhibit moulds, yeasts and some bacteria.

The sodium and potassium salts of sorbic acid are used as fungistatic agents for foods especially on surface and in wrapping materials. These are also used for the preservation of cheese, sweet pickles, etc. for the control of lactic acid fermentation.

Antibiotics: An antibiotic is a chemical produced by microorganism which, inhibit growth or destroy microorganisms. Antibiotics, subtelin and nisin are produced by *Bacillus subtilis and Streptococcus lactis* respectively and used to preserve asparagus, corn , peas, mushrooms, tomatoes and milk. They are more commonly used in canning of processed products and effectively reduce the thermal process requirements necessary to control the spoilage food products.

Chemicals preservations: Antioxidants, butylated hydroxy toluene (BHT) and butylated hydroxyanisole (BHA) are used as food preservative and they inhibit, retard or arrest the growth of microorganisms.

13.9.4 High Pressure Technology

High-pressure technology (HPT) is a new non-thermal process for preservation of fruits and vegetables. This technology is a combination of a high pressure, temperature and time. The process subjects food products to pressures between 50 and 700+ Mpa. High pressures kill microorganisms and inactivate enzymes without the use of heat that can damage the taste, texture, and nutritional value of the food. The mechanism does not promote the formation of new chemicals, "radiolytic" by-products, or free-radicals. By HPT, colour, nutrients, vitamins, and flavour are unchanged and undegraded. Moisture content of fruits and vegetables is very important because very little effect is obtained below 40%. Texture frequently can also be retained but will depend on the initial structure. The texture of high air content foods will likely be changed by HPT.

HPT is applied for the production of high quality shelf stable low acid foods. When combined with a moderate starting (pre-compression) temperatures of 70 to 95^{0}C, spoilage and pathogenic spores are destroyed within less than 1 to 2 minutes. Factors which are important to HPT are process pressure, process temperature (-20^{0}C to 121^{0}C), water activity, and pH.

Fruit based products such as jams, jellies, purees, sauces, fruit juices are processed in HPT at varying pressures 50-700 Mpa, temperature 5-20^{0}C and duration of 2-30 minutes and it improve gelation, faster sugar penetration and reduce the loss of flavour, texture, colour and aroma and nutrients. Inactivate pectinmethlylesterase, polypenoloxidase, peroxidase and lipoxygenase and pathogenic microorganism activity also. Other advantages include: reduced process times, minimal heat damage problems, retention of freshness, flavour, texture and colour and no loss of vitamin C

13.9.5 Cooling

Cooling means storage temperature above freezing and it ranges from 16C to –2.2 C. Cooling will preserve perishable fruits and vegetable for days or weeks depending upon the nature of the food by retarding microbial growth and enzyme reactions at low temperatures. The lower the temperature, the greater the retardation. Various types of cool storage are available.

Cool storage: The temperature in cool rooms where surplus food is stored is usually around 15C. Enzymatic & microbial changes in the foods are not prevented but slowed down considerably. Root crops, potatoes, onions, apples and similar foods can be stored for limited periods.

Cold store or chilling (0 to 5^{0}C): Chilling temperatures are obtained by mechanical refrigeration. Fruits, vegetables and their products can be preserved for a few days to many weeks. The best storage temperature for many foods is slightly above 0^{0}C but this varies with the product. Besides temperature, the relative humidity can affect the preservation of the food. Commercial cold storages (temp.2-5^{0}C; R.H 90-100%) with automatic control of temperature are used for storage of semi-perishable foods such as potatoes and apples and made their availability throughout the year. The growth of bacteria, yeasts, and moulds, and rate of all chemical reactions is slow at or below 10^{0}C, and becomes slower the colder it gets.

13.9.6 Freezing

At temperature below the freezing point of water (–18 to –40^{0}C), growth of microorganisms and enzyme activity are reduced to minimum. Most perishable foods can be preserved for several months if the temperature is brought down quickly and the food is kept at these temperatures. Foods can be quickly frozen in about 90 minutes or less. Quick frozen foods maintain their quality and freshness when they are thawed. Frozen foods should, always be kept at temperatures, below –5^{0}C. Properly frozen (–12 to –17C^0 by excluding air), juice retains its freshness, colour and aroma for a long time.

13.9.7 Microwave

Microwave energy produces heat in materials that absorb and heat foods in a unique fashion that largely eliminate temperature gradients between the surface and centre of food masses. Foods do not heat from the outside to the inside as with conventional heating since microwave penetration can generate heat throughout the food mass simultaneously. The microwaves can result in very rapid heating but requires special equipment, packaging materials, since microwaves will not pass through metal cans or metal foils. Microwave heating produce major differences in food appearance and other properties compared to conventional heating and reduces process time by 90%. Microwave heating increases the temperature of the interior water parts of the solid and has the following advantages: (1) A penetrating quality that leads to uniform drying. (2) Selective absorption by liquid water, which leads to uniform moisture profile within the particle. (3) Ease to control due to rapid response of such heating.

13.9.8 IQF (Individual Quick Freezing)

IQF generally refers to freezing of solid food/pieces/grains like green peas, cut beans, cauliflower pieces, meat, fish etc. While quick freezing relates mostly to liquid, pulpy or semi liquid products like fruit juices, mango/papaya concentrate and purees etc. There is no clumping together of pieces or grains. They remain individual separate pieces. Individual quick freezing have advantages:

- Smaller ice crystals are formed, hence, there is less mechanical destruction of intact cells of the food.
- More rapid prevention of microbial growth.
- More rapid slowing down of enzymatic action.

13.9.9 Ohmic Heating

Ohmic heating, has the advantage that a product containing liquid, solid, or solid-liquid mixtures can, be heated rapidly with a uniform thermal profile. This ensures significant quality retention in comparison to conventional thermal processing, where heat transfer to the interior resulting in significant quality loss. Ohmic heating eliminate bacterial spores. In ohmic heating, the food should possess at least a slight electrical conductivity. Since fats and oils do not conduct electricity, ohmic heating cannot be used in these products.

In transit, ohmic heating could be used to heat the food. The system is light weight, requires minimum space and an electrical power supply, and food packages that can be accommodated between electrodes. It is also suited to the available energy sources (electricity) in transit. This technology is used for simple heating of foods particularly which consists of particles suspended in liquids such as soups.

13.9.10 Drying and Dehydration

Both the terms "drying" and "dehydration" mean the removal of water. Drying is generally done under the influence of non-conventional energy sources like sun and wind. In sun drying, there is no temperature and humidity control. The hottest days are chosen so that the foods dry very fast, thus, preventing from getting spoiled due to souring. Quick removal of the moisture prevents the growth of the microorganisms. Dehydration means the removal of moisture by the application of artificial heat under controlled conditions temperature, humidity and airflow. In this process a single layer of fruit or vegetable, whole or slices is spread on trays, placed inside the dehydrator. The initial temperature of the dehydrator is usually 43°C which is gradually increased to 60-71 °C. Drying is economical and very useful process. Most of the foods contain enough moisture, which encourages action by their own enzymes and microorganisms growth.

Food dehydration cause minimum or ideally no other changes in the food properties and dried to final moisture of about 1-5%. Examples are dried milk and eggs, potatoes flakes, instant coffee, and orange juice crystals. Such products will have storage stability at room temperature for a year or longer. A major criterion of the quality of dehydrated foods is that when reconstituted by the addition of water they are virtually indistinguishable from the original food materials used in their preparation.

13.9.11 Irradiation

Irradiation is a non-thermal technology and involves the use of gamma rays, X-rays or electrons, and uses energy levels that assure no induction of radioactivity in the irradiated product. It retards ripening or senescence of raw fruits and vegetables, sprouting of potatoes. Irradiation will increase the shelf life of foods from 2-5 years. The product must be frozen to achieve stability without major off-flavours. A wide range of products can be preserved by irradiation but primarily it is used to preserve meats. Microorganisms are inactivated by different kinds of radiations. X-rays, microwaves, ultraviolet light, and ionizing radiations, differing in wavelength and energy have been used to preserve food. For all types of radiation, the doses required to sterilize foods, and inactivate enzymes, are generally excessive or borderline from the food quality view point, and all may cause flavour, colour, texture, or nutritional defects. Doses less than sterilizing appear more generally useful to extend storage life. Sub-sterilization doses can inactivate enzymes responsible for initiating vegetable sprouting.

Today, foods are irradiated with ionizing radiation, obtained from radioactive isotopes, which does not rise the temperature significantly and called "cold sterilization". Several foods such as spices, vegetables and fruits, and poultry have been approved for irradiation pasteurization at specific doses in India.

13.9.12 Curing

Curing is a formation of multilayered protective periderm on tuber vegetables after harvest when kept in heaps for 15 to 20 days at ambient conditions to prevent bruising during transport and handling, entry of microorganism and excessive loss of moisture. Plant tissues are covered with protective tissues, which serve to protect the plant from excessive water loss. The primary protective layer is the epidermis but if the plant organ undergoes secondary growth, a multilayered periderm may develop, for example, on apples or potatoes. The epidermis is covered with a waxy cuticle of cutin while the cell walls of periderm tissues generally become impregnated with suberin. Both cutin and suberin can reduce water losses from plant surfaces; however some water loss is inevitable.

13.9.13 Smoking

Smoke is used for preserving foods such as meats and fish. The preservative action generally comes from a combination of factors. Smoke contains preservative chemicals such as small amounts of formaldehyde and other materials from the burning of wood. In addition, smoke generally is associated with heat, which helps to kill microorganisms. This heat also tends to dry out the food, which further contributes to preservation. Smoking over a fire may be quite effective in preserving certain foods; on the other hand, today smoke may be added merely to flavour food, that is, without heat from burning. In meat products, smoke combined with other preservatives is used more for its flavour than for its preservative action.

13.10 HYGIENE AND SANITATION

'Hygiene' describes a system of sanitary principles for the preservation of health. Food hygiene is much more than cleanliness, it involves all measures to ensure the safety, soundness and wholesomeness of food at all stages from its production, processing, manufacturing, packaging, storage, distribution, display for sale and consumption. Food hygiene aims for the production, preparation processing and presentation of food, which is safe for consumer and had good keeping quality. It covers not only the proper handling of foodstuff but also cleanness and sanitization of all the utensils and apparatus used in preparation, premises of food processing unit, service and consumption to eliminate the contamination of food borne microorganism.

The food hygienic measures will involve:

- Protecting food from risk of contamination of any kind.
- Preventing any organisms multiplying to an extent which would expose consumers to risk, or result in premature decomposition of food.
- Destroying any harmful bacteria in the food through cooking or processing.

High standards of food hygiene are essential to prevent food poisoning, food-borne infections, food spoilage, loss of productivity, loss of business, food losses due to premature spoilage or damage, incorrect storage temperature or pest infestations and prosecutions for contraventions of food legislation. Hence, these standards of food must be achieved at a reasonable cost to ensure that the business remains profitable. For it, cost effective hygiene may be considered.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are anti-microbial agents and write their names?

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2. What is the enzyme inactivation and write the names of enzymes involved in colour changes of foods?

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3. Write different treatments to preserve the foods.

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4. Describe the benefits of hygiene and sanitation.

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13.11 LET US SUM UP

Deterioration of food is a decay or undesirable decomposition of constituents by excessive growth of microorganism or by other physical and chemical causes. The deterioration factors are: (1) growth and activities of microorganisms, principally bacteria, yeast, and moulds; (2) activities of food enzymes and other chemical reactions within food itself; (3) infestation by insects, parasites, and rodents; (4) inappropriate temperatures; (5) gain or loss of moisture; (6) oxygen (7) light (8) physical stress and (9) time. Biochemical reactions in foods are catalysed by enzymes and are responsible for undesirable or desirable changes. Nutritional changes occur in foods during storage and processing due to microbiological, enzymatic and chemical reactions. Food-borne diseases cause illness and infections to humans after consumption contaminated foods. Anti- microbial agents are the chemicals which inhibits the growth & development of bacteria, moulds and yeasts. At high temperature enzymatic proteins are denatured and make the enzymes inactive. Different treatments such as thermal, chemicals, high pressure technology, cooling, freezing, microwave, individual quick freezing, ohmic heating, drying and dehydration, irradiation and smoking are done to prevent deterioration or spoilage of food so that it can be stored or preserved in fit conditions for future use. Food hygiene involves all measures to ensure the safety, soundness and wholesomeness of food at all stages: production, processing, manufacturing, packaging, storage, distribution, display for sale and consumption.

13.12 KEY WORDS

Anti-microbial agents :	Chemicals, which inhibits the growth and development of microorganisms.
Bacteria :	They are minute unicellular microorganisms.
Biochemical reactions :	Reactions catalysed by the enzymes in food and plant issues.
Blanching :	Dipping of fruits and vegetables in boiling water or exposing these to steam for a few minutes to kill enzymatic and biological activity.
Cooling :	Use of low temperature to retard chemical reaction and action of enzymes.
Drying and dehydration :	Removal of water.
Enzyme inactivation :	Stoppage of enzyme activity by denaturing them
Food-borne disease :	Disease or infection caused to humans after eating spoiled food
Food deterioration :	Decay or undesirable decomposition of food.
Freezing :	At temperature below the freezing point of water (−18 to −40° C) growth of microorganism and enzymes activity are reduced to a minimum.

High pressure technology	:	It is a non-thermal process for preservation of foods.
Hygiene	:	A system of sanitary principles for preservation of health.
Individual quick freezing	:	Means individual freezing of solid food/ pieces.
Irradiation	:	Exposure to radiation-generally used to sterilize various foods by killing microorganisms.
Microorganisms	:	Very small living beings such as bacteria, yeast and fungi.
Pasteurization	:	The process of killing harmful organisms in a food by heating at controlled temperature below 100°C.
Sterilization	:	Heating at high temperature i.e. 100°C to kill microorganisms.

13.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Shelf life is the time required for a food to reach at unacceptable stage.
   - The retail package of processed foods should have date of manufacture and expiry date to know the self-life.
2. Your answer should include the following points:
   - Microorganism, bacteria, yeast, moulds.
   - Activities of enzymes.
   - Chemical reactions.
   - Moisture, temperature, oxygen.
3. Your answer should include the following points:
   - Enzymatic: lipases, proteases, lipoxygenase, enzymic browning.
   - Chemical: Rancidity and non-enzymatic browning.
   - Physical: loss of texture and flavour.

4. Your answer should include the following points:
   - Clostridoium
   - Salmonella
   - Shigella
5. Your answer should include the following points:
   - Proteins
   - Chemicals

Check Your Progress Exercise 2

1. Your answer should include the following points
   - Anti-microbial agents are the chemicals which inhibits the growth & development of microorganism.
   - Weak acids and work when in the un-ionized form.
   - Sulphur dioxide and its derivatives, Nitrates and nitrites salts, Glycerol esters, Epoxides, p-Hydroxy Benzoate Alkyl Esters (parabens).
2. Your answer should include the following points:
   - Denaturation of enzymic proteins.
   - Blanching.
   - Polyphenoxidase and peroxidase.
3. Your answer should include the following points:
   - Thermal, ohemic heating.
   - Chemical.
   - Cooling, freezing, individual quick freezing.
   - Microwave, irradiation.
   - Smoking.
   - Drying.
4. Your answer should include the following points:
   - Reduction of microorganism contamination.
   - Prevention of food spoilage or decomposition.

13.14 SOME USEFUL BOOKS

1. Jood, S. and Khetarpal, N. (2002) Food Preservation. Agrotech Publishing Acabemy, Udaipur, India

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3. Potter, N.N. and Hotchkiss, J.H. (1996) Food Science (5^{th} Ed). CBS publishers and Distributors, New Delhi.

4. Srivastava, R.P. and Kumar Sanjeev (2^{nd} Edn) (1998) Fruit and vegetables preservation: Principles and Practices. International Books Distributing Co., Lucknow, India

5. Verma, L.R. and Joshi. V.K. (2000) Post-harvest Technology of fruits and vegetables. Indus Publishing Company, New Delhi.

6. Wills, R.B.H., Mc Glasson, W.B., D. Graham Lecture, T.H. and Hall, E.G. (1989) Post-harvest: An Introduction to the physiology and handling of fruits and vegetable. Chapman and Hall, Inc, New York.

UNIT 14 QUALITY ASSURANCE: REGULATION, CODES, GRADES AND STANDARDS

Structure

14.0 OBJECTIVES

After reading this unit, you should be able to answer:

- food safety issues;
- food adulteration, contamination and their detection;
- quality control;
- grades;
- standards;
- enforcement of food laws;
- testing of samples; and
- residue analysis

14.1 INTRODUCTION

Food industry plays an important role in the national economy. For a successful food processing sector, various aspects of total quality management such as quality control, quality system and quality assurance should function for total success. In today's global market, quality and food safety have a competitive edge of enterprises producing foods and providing services to reach the global market. As a member of World Trade organization (WTO), India is signatory to the Sanitary and Phytosanitary (SPS) agreement, and hence has to adopt for international standards, guidelines and recommendations issued by FAO/WHO, Codex Alimentarius Commissions, adoption of food safety standards. The Ministry of Food processing Industries is building awareness among, producers, processors and consumers about the advantages of foods quality, safety and assurance.

14.2 FOOD SAFETY ISSUES

The safety of foods is of utmost significance and has gained a worldwide attention. People have the right to eat the safe and suitable foods. Food borne illness and injuries can be fatal to humans and can damage trade and tourism. Food spoilage is wasteful, costly and can adversely affect trade and consumer confidence. Effective hygiene control, therefore, is vital to avoid the adverse affect on human health and economic consequences of food borne illness, injury and food spoilage. Everyone, including farmers, growers, manufacturers and processors, food handlers and consumers have a responsibility to assure that food is safe and suitable for consumption. These general principles lay a firm foundation for ensuring food hygiene and should be used in conjunction with specific code of hygienic practices. Consumers should also practice clean habits in handling, cooking and storage of food to ensure complete food safety.

In order to understand "food safety" we must first know the terms *safe, hazard,* and *risk.* "Safe" means that nothing harmful happens when we consume a food. A hazard is the capacity of a thing to cause harm. We should first identify hazards related to foods or food components and then estimate the size of the risk that the hazard will cause. It is important to note that all foods have some degree of risk and that no food is absolutely "safe." The important consideration becomes the size of the risk and how the size of the risk can be reduced without eliminating the food source. The goal of food safety is to reduce the size of risks to the lowest reasonable level without severe disruption of the food supply.

14.2.1 Specific Safety Issues

Specific food safety concerns differ markedly and include:

- Additives, colours and flavours.
- Antibiotics and other food additives.
- Fertilizers and other growing aids.
- Irradiation.
- Microbiological contamination.
- Naturally occurring food toxicants.
- Nutrition.
- Pesticides.
- Pollutants.

- Processing, packaging and labelling.
- Tampering.

Consumers are most concerned about pesticides and additives as both are linked to cancer and not to microbiological contaminations, however food industry is most concerned about the microbiological safety of its products. In addition, many quality control checks are made to ensure that foods are free of extraneous matter such as glass, machine fillings and insect parts. Many food industries adopt 'Good Manufacturing Practice (GMP) and 'Hazard Analysis and Critical Control points (HACCP)'. Which assure that products manufactured under proper conditions and sanitation and hygiene will not have chance of contamination or error during processing.

14.3 FOOD ADULTERATION, CONTAMINATION AND THEIR DETECTION

14.3.1 Food Adulteration

Food adulteration is defined as the process by which the quality or the nature of a food product is adversely affected through the addition of a foreign or an inferior substance and the removal of a vital element. Adulteration of food may endanger health. Adulteration may be intentional or unintentional. The intentional adulteration is a willful act while the incidental adulteration is usually due to ignorance or lack of proper facilities.

Intentional adulterants: These adulterants are mixed with the food intentionally to increase the weight and quantity to make more money. Examples, sand, marble chips, stones, mud, other filth, talc, chalk powder, water, mineral oil and harmful colours.

Incidental adulterants: Pesticide residues, tin from can, droppings of rodents, larvae in foods. Some foods contain toxic pesticides, and the rodents & insects also introduce excreta, secretions and microorganisms responsible for food spoilage and intoxication.

14.3.2 Food Contamination

Food products are mostly contaminated with soil, air and water-borne microorganisms. Harvesting, processing, distribution and preparation generally contaminate the foods and food products which transmit certain food poisoning micro-organisms causing infections or intoxications or illness in humans. Food contaminations can be defined as the transference of any objectionable matter into or on the food. Following are 3 types of contaminations.

Contamination by microorganisms (bacteria, moulds or viruses): Generally occurs in raw foods such as vegetables grown on sewage, contaminated food premises, inadequate space and poor design. This type of contamination by microorganisms is the most serious and may result in food spoilage, food poisoning or even death.

Bacterial contamination is most significant as it results in large amount of spoilt food and large number of food poisoning cases. Bacteria are found everywhere: in soil, air, water, plants, animals, human and foods. Certain bacteria release toxins and cause death of persons consuming contaminated food. Some bacteria such as *Clostridium botulinum, Staphylococcus aureus,* *Salmonella bacteria* and *Bacillus cereus* are the common causes of food illness in humans.

Mould spores are found in atmosphere, on damp surfaces and on mouldy food. If food is stored at the wrong temperature at high humidity and in excess of the recommended shelf life, there are chances of food contamination.

Viruses like Hepatists A, Norwalk virus group and Rotavirus etc. are usually spread into food premises by food handlers who are carriers or on raw foods which have been grown in sewage polluted water and cause illness.

Yeasts grow best in the intermediate acid range, a pH of from 4.0 to 4.5. Food that is highly contaminated with yeasts will frequently have a fruity odour.

Physical contamination: Foreign bodies such as dust, dirt, stones etc. found in food may be brought into food premises with the raw materials or introduced during storage, preparation, service or display. Bolts, nuts, other pieces of metals, staples, cardboard string, polythene, rodent droppings, eggs and larvae of insects, cigarette buts, glass, wood splinters, paint or dust hair and fingernails, buttons and combs of persons handling the food are generally the sources of physical contaminations. Care should be taken that they do not contaminate the food.

Chemical contamination: Unwanted chemicals can enter the food during growth e.g. fertilizers, pesticides, environmental contaminants such as led or dioxins; during processing e.g. oil, cleaning chemicals; during transport as a result of spoilage or leakage and during sale etc.

14.3.3 Food Quality Assurance

Quality assurance includes the *planning* and *surveillance* of everything to do with quality throughout the company. Quality assurance seeks to generate confidence both within the organization and externally, among its customers, that their requirements will be fulfilled. Among the additional features acquired in the progress from quality control to quality assurance are the following:

- The definition of a quality policy and objectives;
- The development of a quality manual;
- Ensuring competency of personnel;
- Conducting periodic internal audits;
- The elimination of the root causes of the problems found; and
- Periodic reviews of the system by top management.

Above all, there is a shift in emphasis from mere detection to prevention of non-conformance. For introduction quality assurance system in the food industry good hygienic practices, a good agricultural practices, and good environmental practices for various industries should be adopted. The standards should become essential for introduction of quality assurance system in food industry in the form of potential hazards, GMP, HACCP, ISO:9000, Codex Alimentarius standards etc.

The Codex Alimentarius general principles of food hygiene are aimed to:

- identify the essential principles of food hygiene applicable throughout the food chain (production to consumption), to achieve that food is safe and suitable for human consumption;
- recommend a hazard analysis and critical control point (HACCP)- based approach to enhance food safety;
- indicate how to implement those principles; and provide a guidance for specific codes which may be needed for – sectors of the food chain; processes; or commodities; to amplify the hygiene requirements specific to those areas.

These principles are recommended to Governments, industry (including individual primary producers, manufacturers, processors, food service operators and retailers) and consumers alike.

14.3.4 Commercial Item Description

Commercial item description is defined under FPO standards (Govt. of India) for each processed food product which consists code number, whether concentrated or unconcentrated, sweetened or unsweetened, pasteurized or unpasteurized , made from ripe fresh and good quality fruits or vegetables, added water or not, and details of preservative, emulsifying, stabilizing agents i.e. name, quantity and quality (food grade). It also includes the quantity of total soluble solids, sugars, vitamins and addition of salt, colour etc. A label has to be fixed on the processed products mentioning date of manufacture, date of expiry, total weight of product, and nutritive composition the product i.e. total carbohydrate, fats, proteins, fibre, name of additive etc. Following are the few examples:

FRUIT JUICE means the unfermented and unconcentrated liquid expressed from sound, ripe fresh fruit and with or without:

a) sugar, dextrose, invert sugar, or liquid glucose, either singly or in combination;

b) water, peel-oil, fruit essences and flavour, common salt, ascorbic acid, citric acid, and preservatives.

The acidity of the finished product calculated as citric acid shall not be less than 4% in the case of pure lemon juice or pulp and not less than 5% in the case of pure lime juice but shall not exceed 3.5%t in the case of other juices.]

The total soluble solids for sweetened fruit juice (except tomato juice) shall not be less than 10%. It may also contain permitted emulsifying and stabilizing agents as prescribed in rule 61 C. It may also contain fumaric acid certified by BIS to the extent of 0.3%.

Tomato Juice means canned or bottled, unconcentrated, pasteurized juice expressed from tomatoes with a proportion of the pulp, expressed with or without the application of heat by any method that does not add water to juice, from whole, ripe tomatoes from which all stems and objectionable portions have been removed and with or without (a) salt (b) sugar, or dextrose, or both added in dry form (c) citric acid, malic acid or ascorbic acid. Provided that canned tomato juice may also contain extraneous permitted colour. The total soluble solids w/w shall be not less than 5 % ([free of salt). It may also contain permitted emulsifying and stabilizing agents as prescribed in rule 61-C. [It may also contain fumaric acid certified by BIS to the extent of 0.3 %.

Fruit Syrup means sweetened fruit juice containing, sugar, dextrose, invert sugar or liquid glucose either alone or combination, with or without:(a) water, peel-oil, fruit essences and flavours, common salt (b) citric acid, ascorbic acid.(c) permitted preservatives and colours. The total soluble solids w/w shall not be less than 65 %. The minimum percentage of fruit juice in the final product shall not be less than 25% w/w. It may also contain permitted emulsifying and stabilising agents as prescribed in rule 61-C.It may also contain fumaric acid (food grade) certified by BIS to the extent of 0.3 %.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the food safety issues?

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2. Name the most common bacteria to cause food borne illness.

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3. What are good hygiene practices and standards for food safety?

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14.4 QUALITY CONTROL

Quality control (QC) is a means of detecting whether quality has been achieved and of taking action to correct any deficiencies. QC activities include:

- Establishing the specifications of the parameters to be controlled;
- Preparing quality plans for control;
- Performing checks or inspections;
- Diagnosing and taking action on the variations observed; and
- Checking that the variations have been corrected.

The fundamental purpose of a quality control program is to acquire dependable information on all the attributes of a product which affects its quality. Quality control ensures that raw materials meet set standards, processing methods should be performed as designed, finished products meet company standards and consumer confidence in the enterprise remains high. The basic functions of a quality control programme are:

- Physical and chemical evaluation of raw materials and processed products.
- Control of
  a) Raw materials, ingredients and packaging supplies.
  b) Processing parameters.
  c) Finished products.
- Microbiological analysis and control of raw materials and finished products.
- Control of storage and handling conditions.
- Sanitation and waste products control.
- Assurance that final products are within the legal and marketing standards established.

Quality control in fruits and vegetables begins in the field with the selection of proper time of harvest for maximum quality. Each subsequent step after harvest is to maintain quality and include the following step:

Operation	**Procedures**
Harvesting	Check maturity of commodity with respect to colours size, firmness etc.
Preparation for market	• Monitor various steps such as washing, sorting, waxing, sizing, post harvest treatments etc. • Check shipping containers for compliance with grade, size and weight regulations.
Cooling	Monitor product temperature at key points in the handling system, especially before and after cooling.
Transportation	Check transit vehicle for cleanliness, before loading, loading pattern, load immobilization etc.
Destination markets	Check quality and condition of the product and shipping containers at destination market.

Quality control personnel should devote full time and attention to their duties and make needed changes in the harvesting and handling operation as and when required to maintain the desired quality.

Quality control within a food manufacturing industry demands constant vigilance at all stages in processing, so that any necessary adjustments can be made at the appropriate time. The specific responsibilities of quality control is to ensure that the system used produces a standard product with acceptable quality in respect to nutrition, purity, wholesomeness and palatability. The specific responsibilities of quality control assigned to a department or to an individual include:

- Standardizing procedure for sampling and examining raw materials. Development of test procedures.
- Establishment and implementation of quality standards for fresh and processed products.
- Setting up preventive quality control methods for in-plant liaison between manufacturing section and test laboratories.
- Examination of finished products.
- Storage controls.
- Research and development into new products and their packaging.

Quality control leads to:

- Raw material control
- Process control
- Inspection of finished products
- Sensory evaluation or evaluation of the acceptability of the final product.
- Packaging
- Labelling and storage

14.4.1 Inspection

The objective of inspection is product conformance by screening out conforming products from nonconforming products, which is done by visual checks/ measurements; then testing and reporting. Under a simple inspection-based system, one or more characteristics of a product are examined, measured or tested, and compared with specifications to assess conformity. Products that do not conform to specifications are reworked, or regraded, or accepted with concessions, or rejected. This system is used for inspecting incoming goods, checking a product at intermediate stages, or inspecting a product ready for delivery to the customer. Using inspection to improve quality is too late, too costly and ineffective. In processing fruits and vegetables for export continuous inspection is applied. The inspection of raw materials should be carried out at the commencement of each processing run to ensure that only good quality fruits or vegetables of sufficient maturity are used for processing. Sampling checks of raw materials should be carried out frequently. Raw material and ingredients must be inspected and sorted to insure that they are clean, wholesome and fit for processing. Containers and carriers (such as trucks or railcars) should be inspected to assure that their condition has not contaminated raw ingredients

14.4.2 Lab Tests

The laboratory tests used in quality control are usually standard scientific tests for physical, chemical, microscopic and microbiological analysis. By adopting these tests one should be in a position to reproduce same results by any trained quality control technician. Physical tests include product characteristics such as size, weight, colour, texture and adulterants like, glass, stone, filth and insects. The processed products should be of prescribed size, weight, colour, texture etc and devoid of physical adulterants. The chemical tests for the estimations of moisture, protein, carbohydrates, minerals, fats, vitamins and fibre contents should be standards practice from the raw material and processed products for the prescribed quality. Microscopic and microbial tests are used to determine the presence of moulds, microbes and insect fragments or foreign materials, spoilage or disease microorganisms from the raw and finished products to obtain disease free foods. The tests assure that the final products are disease free, within the legal and marketing standards established.

14.4.3 Sanitation

The raw produce, processed foods, processing units and persons working in food processing units must be kept in good sanitary conditions to minimize the possibilities of contamination by microorganism, chemicals and physicals adulterants. The persons working in food units should not have any disease and must wear clean clothes, maintain a high degree of personal cleanliness and must wash or sanitize hands thoroughly before starting work and at any other time when the hands have become soiled. The food processing plant must be free from litter, waste or refuse; potential for foot-borne filth or breeding places for insects or microorganisms.

The processing units must be kept in good sanitary condition to minimize the possibility of contaminating foods or equipment that contact food. Pesticides, insecticides and rodenticides may be used to prevent contamination by pests, insects and rodents respectively. All utensils and equipment surfaces that contact food must be cleaned and sanitized before use to prevent food contamination. When utensils or equipment are used in a continuous production operation, they must be cleaned and sanitized on a predetermined schedule. The water which comes into contact with food or processing equipment must be safe and of good sanitary quality. The disposal of sewage water should be proper so that it must flow into sewage system or disposed of through other adequate means. Toilets and hand-washing facilities must be provided inside processing centres for workers. Raw materials must be washed or cleaned to remove soil and other contamination by sanitary quality water. Food processing equipment must be kept in a sanitary condition through frequent cleaning and, when necessary, sanitizing. If ice is used and comes in contact with food products, it must be made from potable water and be in a sanitary conditions.

14.4.4 TQM (Total Quality Management)

TQM requires the creation and continual improvement of processes, along with other quality assurance activities. Companies or organizations aspiring to quality management are characterized by the widespread application of the concept that everyone in the organization has customers and that their satisfaction should be enhanced; in this way, everyone is committed to continually improving their part of the operation.

a) TQM is a process designed to focus external/internal customer expectations preventing problem building, commitment to quality in the work force and promoting open decision-making.

b) TQM is an effective system for integrating quality development, quality maintenance, and quality improvement efforts of various groups in the organization so as to enable products and services at the most economical level, which allows customer satisfaction.

c) TQM is a building, housing the quality assurance system, quality consciousness of employees as the foundation, employee's involvement and commitment as the walls, the quality policy of the management as the roof.

d) TQM is an integrated organizational approach in delighting customers by meeting their expectations on a continuous basis through every one involved with the organization, working on continuous improvement in all products/services/processes along with proper problem solving methodology.

e) Meaning of Total Quality Management

Total	Every one associated with the company is involved in continuous improvement, in all functional areas, at all levels.
Quality	Customers expressed and implied requirements are met fully.
Management	Executives are fully committed Effective utilization of resources Decision in a planned way To maintain existing level of quality To improve existing level of quality.

14.4.5 Codex Alimentarius

The Codex Alimentarius is a collection of international standards for the safety and quality of foods as well as codes of good manufacturing practice and other guidelines to protect the health of the consumer and remove unfair practices in International trade. This is based on the recommendation of FAO and WHO, a worldwide conference for food standards and guidelines that would protect consumer's health and ensure international fare trade practices. Codex standards comprise standards for processed frozen fruits and vegetable, fruit juices, fats and oils, milk products, cereals and pulses, fish and poultry products, coca products and standards methods of analysis. Codex has also brought a list of more than 1000 food additives along with their permitted levels for use in different foods. The Codex general principles of food hygiene are aimed to: a) identify the essential principles of food hygiene applicable throughout the food chain to achieve the goal of ensuring that food is safe and suitable for human consumption. b) recommend a HACCP based approach as means to enhance food safety. c) indicate how to implements those principles and d) provide a guidance for specific codes which may be needed for – sectors of food chain; process; or commodities; to employ the hygiene requirements specific to those area.

14.4.6 HACCP (Hazard Analysis and Critical Control Point)

HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product. Food safety systems based on the HACCP principles have been successfully applied in food processing plants, retail food stores, and food service operations.

Advantages

- Focus on identifying and preventing hazards from contaminated food is based on scientific principles.
- Permits more efficient and effective monitoring at government level, primarily because the record keeping allows investigators to see how well a firm is complying with food safety laws over a period rather than how well it is doing on any given day.
- Places responsibility for ensuring food safety appropriately on the food manufacturer or distributor.
- Helps food companies complete more effectively in the world market
- Reduces barriers to international trade.

The HACCP is based on 7 principles, which have been universally accepted by government agencies, trade associations and the food industry around the world. These include:

1. **Assessment of hazards:** Each unit operation should be evaluated to identify potential source of microbial, chemical and physical hazards, which may be introduced into the produce. Areas, which should be evaluated, are growing and harvesting operations, packing shed operations, packaging material and storage as well as distribution. This process is best accomplished by a team of both management and production personnel.
2. **Determine critical control points (CCP) to control the identified hazards:** The next step in developing a HACCP program is to draw a flow diagram for your specific operation and then determine where each of the identified hazards may be monitored. Each point that will be monitored to control specific hazard is now designed a critical control point.
3. **Establishment of CCO limits:** Once CCP have been identified, tolerance limits must be set to determine when corrective action needs to be taken. Tolerance must be observable and measurable.
4. **Established of CCP monitoring procedures:** How often monitoring will be done, how measurements will be taken and what documentations will be prepared must next be clearly defined.
5. **Corrective action when deviations from CCP limits occur:** When a deviation from the prescribed limits occurs corrective action must be taken to eliminate the potential contamination. All deviations and corrective actions must be noted in written form.

6. **HACCP record keeping system:** All paper work related to the HACCP system must be kept in an orderly and accessible manner. Records that should be kept include:

   - Production Records
   - Supplier audits
   - Pesticides usage and testing results
   - Irrigated water test results etc.
   - Harvesting Records:
   - Harvest dates and lot numbers
   - Total number of boxed harvested, etc.
   - All critical control point monitoring records
   - Storage and distribution records
   - Temperature monitoring
   - Truck cleanliness etc.

7. **Deviation file:** HACCP deviations and corrective actions taken.

   HACCP verification: Periodic HACCP plan review including review of CCP records, deviations and random sampling to verify that the HACCP program must be done to assure that HACCP program is functioning properly. This review should be done either on a monthly or quarterly basis.

14.5 GRADES

The quality of agricultural produce, cereals, spices, oil seeds, legumes, fruits and vegetables has criterion for the categorization into various grades depending upon the degree of purity in each case. The grades incorporated are grades 1,2,3 and 4 or special, good, fair and ordinary.

Grading of some commodities like vegetable oils, *atta,* spices and honey is voluntary. The grading of commodities like tobacco, walnuts, spices, basmati rice, essential oils, onions, potatoes meant for export is compulsory under government acts to ensures the quality of produces. Grading add extra cost and hence the graded products are priced slightly higher. The grading of agri-cultural commodities has three main purposes. Firstly, it protects the consumer from exploitation. By knowing the quality and grade of his produce, he is in better bargaining position against the trader. Secondly, it serves as a means of describing the quality of the commodities to be purchased or sold by the buyers and sellers all over the country and abroad. This establishes a common trade language and avoids the need for physical checking and handling at many points. Thirdly, it protects the consumer by ensuring the quality of products he purchases

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the basic functions of quality control programme?

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2. Why inspection and grading are required in food processing?

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3. What is codex Alimentarius?

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4. Write the seven principles of HACCP.

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14.6 STANDARDS

Food standards for ensuring the quality and safety of raw and processed foods for human consumption have been formulated and enforced by law in India. Food standards have been also prescribed based on the International Codex Alimentarius with suitable modification to suit Indian conditions thus in India food processing and allied industries are governed by following different standards.

14.6.1 ISO (International Organization for Standardization) 9000 SERIES

ISO 9000 series are quality management and quality assurance standards. The principal of these standards is, 'if the system (input, process, output) through which the product is produced, is perfect then the product coming out of system will also be perfect'. This series of standards for quality assurances is now being adopted by most of the companies in India and abroad. More and more companies are in the queue for achieving this quality System Certificate. ISO 9000 series of standards are available which provide the guidelines for the establishment and management of quality system in the organization.

There are 4 basic models for classification of ISO 9000 Series:

ISO 9001 : Model for design, development, production, installation and servicing.

ISO 9002 : Model for production, installation and servicing.

ISO 9003 : Model for final inspection and testing.

ISO 9004 : Model for quality management and quality system element.

There are laid down guidelines on how to develop and follow systems as per the requirement of this series: The series covers the following major clauses**:** Management responsibilities, Quality systems, Contract review, Design control, Document control, Purchase, Purchaser supplied product, Product Identification and Traceability, Process control, Inspection and testing, Inspections and testing of measuring equipments control of nonconforming product, Corrective preventive action, Handling, storage, packaging and delivery: Quality records, Internal Quality audit, Training, service and statistical techniques

The main principal of achieving this certification is 'SAY what you Do and Do what you SAY'

14.6.2 Fruit Product Order (FPO)

Central Govt. formulated Fruit Product Order (1955 and 1961) which lays down statutory minimum standards in respect of the quality of various fruits, vegetables products and processing facilities. Packaging fruits and vegetables to standards below the minimum prescribed is an offence and punishable by law. Periodic inspection by inspectors is carried out to ensure conformity of standards by processors. Every manufacturer of fruit and vegetable products must obtain a license for manufacture and conform to the sanitary requirements and standard of quality specified. The inspectors are empowered to collect samples and inspect the factory and send the coded samples to Central

Laboratory. The order has laid down limits for the presence of poisonous elements. The act has laid down the standard specifications for the food products and food additives.

14.6.3 Meat Products Order (MPO)

This order regulates manufacture, quality and sale of meat and all meat products . Provisions are meant to control production, quality and distribution of raw and processed meat. This makes it illegal to transport meat unless it has been prepared and processed according to the provisions of the order and carries the mark of inspection. It provides means to (a) detect and destroy meat of diseased animals (b) ensure that the preparation and handling of meat and meat products is conducted in a clean and sanitary manner (c) Prevent the use of harmful substances in meat foods. (d) See that every piece of cut meat is inspected before sale to ensure its wholesomeness. The order also lays down the rules and conditions for procedure to be adopted for the selection of disease free animals, slaughterhouse practices and further treatment of the meat so as to maintain the meat in a wholesome manner, devoid of pathogens.

14.6.4 Cold Storage Order (CSO)

The cold storage order (CSO), 1980, promulgated under the Essential Commodities Act, 1955, has the objective of ensuring hygienic and proper refrigeration conditions in a cold store, regulating the growth of cold storage industry and rendering technical guidance for the scientific preservation of food stuffs in a cold store and prevent exploitation of farmers by cold storage owners. Agricultural Marketing Advisor to the Government of India is the licensing officer under this order.

14.6.5 PFA (Prevention of Food Adulteration Act and Rules in India)

Indian Government promulgated Prevention of Food Adulteration Act of 1954 to ensure that food articles sold to the customers are pure and wholesome. It also intended to prevent fraud or deception and encourages fair trade practices. The act was amended twice to plug the loopholes of escape and to ensure stringent punishment. The act prohibits the manufacture, sale and distribution of not only adulterated foods but also foods contaminated with toxicants and misbranded foods. A central food laboratory at Calcutta was established for the purpose of reporting on the suspected food products. A Central Committee for food standards has been constituted under the Act and has been charged with the function of advising the Central Government on matters relating to Food Standards. Provisions have been made in the Act for the appointment of Food Inspectors by the state Governments and their powers have been defined. The State Governments set up food testing laboratories and appoint Public Analysts with adequate staff to report on suspected foods. Standards have been laid under the PFA Act for various categories of food and according to PFA Act, a food shall be deemed to be adulterated if it does not meet the specified conditions mentioned in the Act.

14.6.6 AGMARK

The word ‘Agmark’ is a derivative of Agricultural Marketing. The Agmark standards were set up by the Government of India by introducing an Agricultural Produce Act in 1937. The Agmark seal ensures quality and purity. The quality and grade of product is determined with reference to the size, variety, weight, colour, moisture, fat content and other factors. The Act defines the quality of cereals, spices, oil seeds, butter, ghee, legumes and eggs and provides criterion for the categorization of commodities into various grades. The grades incorporated are grades 1,2,3 and 4 or special, good, fair and ordinary. The standards also specify the types of packaging to be used for different products. The physical and chemical characteristics of products are kept in mind while formulating the Agmark specifications. The Central Agmark Laboratory at Nagpur carrying out research and development work. The Certificate of Authorization is granted only to those in the trade having adequate experience and standing. The staff of the Directorate of Marketing and Inspection or of the State Government is generally present at the time of selection of goods, their processing, grading and packing before applying the appropriate AGMARK labels.

- Agmark products are free from adulteration and conform to the scientifically laid down principles of purity. It ensures consumer protection.
- Each batch of Agmark products is pre-tested for quality by quality control and trained chemist.
- Agmark products are always packed in food grade material never to be sold loose.
- Agmark products bear Agmark label or replica as an identification mark, date of manufacturing and expiry period.
- Free of cost replacement provided in the rules if Agmark products are found not conforming to the quality standards.
- They are not mandatory, any body can use them.

14.7 ENFORCEMENT OF FOOD LAWS

Food standards for ensuring the quality and safety of raw and processed foods for human consumption have been formulated and enforced by law in India. The laws and regulations exist to deal with food safety and consumer concerns about food contamination and adulteration, penalizing the seller of diseased, unwholesome and corrupted food products. The law defines foods, food preservatives and artificial colour, and ban the sale of food prepared under unsanitary conditions or containing any deleterious or unsafe substances. These also specify standards of quality for various classes of foods and outline the conditions under which a food would be regarded as adulterated or misbranded. Finally, there are statutory or legal obligations, which need to be fulfilled for safeguarding the health and well being of people and the establishment.

There are number of food laws being implemented by various Ministries/Departments of Indian Government. These are primarily meant for 1) Regulation of Specifications of Food, and 2) Regulation of Hygiene conditions of Processing and Manufacturing. The Government of India has also empowered several agencies and promulgated a number of acts and orders to ensure food safety. Agencies and institutes have also been created to lay down standards for quality of foods. The manner in which the food is processed and packed is also covered by a number of regulations. Some of these food quality assurance laws are voluntary and some are mandatory. The following are various food laws operating in India.

1. Prevention of Food Adulteration Act, 1954 and Rules 1955.
2. Agriculture Produce Act 1937 (AGMARK) Grading and Marketing.
3. Bureau of India Standards (BIS).
4. Environment Protection Act 1986 & Rules 1989.
5. Export Quality Control and Inspection Act, 1963.
6. Essential Commodities Act, 1955.
7. Insecticide Act, 1968.
8. Fruit Product Order, 1955.
9. Meat Food Product Order, 1973.
10. Solvent Extracted Oil, De oiled Meal and Edible Flour (control) order, 1967.
11. Milk and Milk Product Order, 1992.

PFA are enforced by the Department of Health. Under the law, slaughter houses, markets, factories, warehouses and other establishments involved in food trade may be inspected to ascertain that the raw materials as well as processing, packaging and storage facilities are sterile and ingredients meet the minimum standards prescribed by the law. Adulterated and misbranded products may be seized by inspectors, destroyed and legal action be taken depending upon the nature of the offence.

Food laws came into existence for a number of reasons:

i) To maintain the quality of food produced in the country;
ii) To prevent exploitation of the consumer by the sellers;
iii) To safeguard the health of the consumers;
iv) To establish criteria for quality of food products, since more and more foods were eaten in processed, rather than natural forms. This has resulted in the inability of the consumer to identify the quality of the contents that could be identified easily.

The legislation which is directly concerned with the protection of the health of consumers and the quality of food products marketed is the Prevention of Food Adulteration (PFA) which states that an article of food shall be deemed to be adulterated. The PFA Act, thus, lays down the guidelines for setting up standards for various food items like cereals and cereals products, pulses, ghee, etc. All processed items which, are mass-produced for public use, are expected to conform to these standards.

In addition to the mandatory acts and orders cited above, agencies such as Bureau of Indian Standards (BIS) and Directorate of Marketing and Inspection have also laid down quality standard for foods.

Operating quality systems as per quality system standards leads to doing right things on time, all the time and always to the customer's satisfaction

14.8 TESTING OF SAMPLING

The Food Health Authority (FHA) at State level is the Director of Public Health and Preventive Medicine. It is responsible for the good quality and standards of foods available to the consumers. Under FHA, the Local Health Authority appointed in each city of every State is responsible for testing of samples. The food inspector is appointed by the Central or State Government and they are trained in food inspection and sampling and have the powers to take sample of any food article from 1) any person selling such article 2) any person who is in the course of delivering or preparing to deliver such article to a purchaser or consignee 3) a consignee after delivering of any such article to him, and to send such samples for analysis to the Public Analyst (PA) of local area. When the Food Inspector wants to lift the suspected food, the shopkeeper must first be informed and there should be a witness present also. 150 g of sample is necessary to be sent for analysis but usually 600 g of sample is collected and sent to Central Food Laboratory Calcutta, and Central Food Technological Research Institute, Mysore. There is a recommended procedure to collect the sample and seal it in a bottle. The sealed bottle has a label on it in which the code number of the inspector, address of the shop, date and time of collection are written. When individuals doubt adulteration in foodstuffs they have to inform the Food Health Authority. Samples can be sent for analysis only after getting order from Food Health Authority. If the persons are found guilty of selling adulterated food, the persons involved can be convicted. A vendor found adulterating the food with ingredients injurious to health is liable for a much heavier sentence than a vendor involved in only mixing an inferior ingredient not injurious to health.

14.9 RESIDUE ANALYSIS

The foods require the absence of harmful substances like pesticides that are harmful for human health. The estimation of pesticides residues in foods is very important and the declaration of pesticides qualitatively or quantitatively has become inevitable for export and import. About 176 pesticides are listed which come into foods from their intentional or unintentional use on the crops. The maximum residue limits vary with the type of commodity. Use of many pesticides is restricted by law and the maximum residue limits commonly used pesticides are fixed by national (PFA in India) and international (Codex Alimentarius Commission) agencies.

Analysis of pesticides in foods is very cumbersome job and requires standards procedures and specific instruments. The basic steps for sampling and analysis of pesticides are given below:

Sampling ⟶ Sample preparation ⟶ Extraction of pesticides ⟶

Partitioning ⟶ Cleanup, Concentration of extract ⟶ Dilution with

appropriate solvent ⟶ Identification & estimation of pesticides

(GC, HPLC, Mass Spectrometer, GC-MS, UV-VIS Spectrometer, TLC etc.)

The sampling procedures and quantity for sampling varies with the commodity and type of sample. The sample should be drawn as uniform as possible from whole lot of produce.

Residue analysis consists of a chain of procedures. The analyst should be an experienced and competent in residue analysis. The laboratory requires an adequate range of reference standard pesticide of high purity. The range should cover all parent species and their metabolites. Chemical reagents, adsorbents and solvents should be high purity and not to interfere in the analysis. All glassware, reagents, solvents and water should be checked from contaminants before use. In a routine laboratory monitoring for compliance with national tolerances, standardized methods will be used and these should be validated periodically.

A number of instrumental procedures for estimation/confirmation are used in residue analysis. Gas chromatography (GC) is the commonly used instrument for qualitative and quantitative determination of pesticides residues. The specific columns and detectors are used for different groups of pesticides. Thin layer chromatography (TLC) is also used in some instances, confirmation of gas-chromatographic findings and identification most conveniently achieved by TLC. The advantages TLC are speed, low cost and applicability to heat sensitive materials but it has lower sensitivity than GC. High performance liquid chromatography (HPLC) can be used advantageously for the confirmation of residues initially found by gas chromatography or by other techniques and may be in certain circumstances the preferred quantitative technique. Mass spectrometers (MS**)** are generally sensitive at the nanogram level.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is ISO 9000 and write it's basic models?

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2. What is AGMARK and the advantages of AGMARK?

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3. Name the different Acts and Orders to enforce the quality of food in India.

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14.10 LET US SUM UP

The safety of foods is of utmost significance as people have the right to eat the safe and nutritious foods. Adulteration of food may be intentional or unintentional it endangers the health of consumers. Food products are mostly contaminated with microorganisms, (bacteria, moulds or viruses), and physical (dust, dirt, stones etc) & chemical (fertilizer, pesticides) contaminants. Quality assurance includes the *planning* and *surveillance* of everything to do with quality throughout the company and it generates confidence among consumers and customers. For introduction of quality assurance system in the food industry, good hygienic practices, good agricultural practices, and good environmental practices for various industries should be adopted. The standards should become essential for introduction of quality assurance system in food industry. Quality control ensures that raw materials meet set standards, processing methods perform as designed, finished products meet company standards and consumer confidence in the enterprise remains high. The specific responsibility of quality control is to ensure that the system used produces a standard product with acceptable quality in respect to nutrition, purity, wholesomeness and palatability. The objective of inspection is product conformance by screening out conforming products from nonconforming.

The raw produce, processed foods, processing units and persons working in food processing units must be kept in good sanitary conditions to minimize the possibilities of contamination by microorganism, chemicals and physicals adulterants. Total Quality Management requires the creation and continual improvement of processes, along with other quality assurance activities. The Codex Alimentarius is a collection of international standards and codes for the safety and quality of foods. HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product. Food standards for ensuring the quality and safety of raw and processed foods for human consumption have been formulated and enforced by law in India. The laws and regulations exist to deal with food safety and consumer concerns about food contamination and adulteration, penalizing the seller of diseased, unwholesome and corrupted food products. The estimation of pesticides residues in foods is very important and the declaration of pesticides qualitatively or quantitatively has become inevitable for export and import foods. Identification & estimation of pesticides residues is done by GC, HPLC, Mass Spectrometer, GC-MS, UV-VIS Spectrometer, TLC etc.

14.11 KEY WORDS

Adulterated	**:**	The deliberate addition of inferior or cheaper material to a supposedly pure food product in order to stretch out supplies and increase profits.
Bacteria	**:**	Single celled microscopic organism.
Chemical sanitizers	**:**	Products used on equipment and utensils after washing and rinsing to reduce the number of disease – causing microbes to safe levels.
Contamination	**:**	The unintended pressure of harmful substances or conditions in food that can cause illness or injury to people who eat the infected food.
Critical control point (CCP)	**:**	means a point or procedure in a specific food system where loss of control may result in on unacceptable health risk.
Codex alimentarius	**:**	Is a collection of international standards and codes for the safety and quality of foods.
Disnifact	**:**	destroy harmful bacteria.
Food borne illness	**:**	An illness caused by consumption of a contaminated food.
Grade standards	**:**	Principally standards of quality to help producers, wholesalers, retailers, and consumer's in marketing and purchasing food products.
HACCP	**:**	called *hassip* is a management system in which food safety is addressed.
Juice	**:**	the aqueous liquid expressed or extracted from one or more fruits or vegetables or any concentrations of such liquids.
Sanitation	**:**	maintenance of conditions which are clean and promote good health.

14.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Additives, colour and flavour.
   - Microbiological contamination.
   - Pesticides, fertilizers, food toxicants, pollutants etc.

2. Your answer should include the following points:

   - *Clostridium botulinum.*
   - *Salmonlla.*

3. Your answer should include the following points:

   - Good Manufacturing Practices
   - HACCP
   - Codex Alimanterius
   - ISO : 9000

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Physical and chemical evaluation of raw & processed material.
   - Control of raw material, processing parameter and finished products, storage and handling conditions.
   - Microbiological analysis.

2. Your answer should include the following points:

   - Product conformance.
   - Grading is done for purity and quality of product.
   - Fetch better price.

3. Your answer should include the following points:

   - Collection International standards and codex for quality and safety foods.
   - Recommended HACCP to enhance food safety.
   - Identify principles of food safety.

4. Your answer should include the following points:

   - Assessment of hazards.
   - Determine Critical Control Points (CCP).
   - Established of CCP limits.
   - Established of CCP Monitoring procedures.
   - HACCP record keeping system.
   - Deviation file.
   - HACCP verification.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Quality management and quality assistance international standards.
   - ISO:9001, ISO:9002, ISO:9003, ISO:9004 for design, production, inspection and testing and quality management etc.

2. Your answer should include the following points:
   - Agricultural Produce Act, 1937.
   - Derivative of Agricultural Marketing.
   - Products are free from adulteration.
   - Pre-tested product quality and bear AGMARK seal.
3. Your answer should include the following points:
   - Prevention of Food Adulteration Act, 1954 and Rules 1955.
   - Agriculture Produce Act 1937 (AGMARK) Grading and Marketing.
   - Bureau of India Standards (BIS)
   - Fruit Product Order, 1955
   - Meat Food Product Order, 1973.

14.13 SOME USEFUL BOOKS

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EXPERIMENT 1 EQUILIBRIUM MOISTURE CONTENT (EMC)

Structure

1.1 INTRODUCTION

Food materials tend to absorb or lose moisture according to the environmental conditions. They will absorb moisture when partial vapour pressure of the water inside the grain is less than the partial vapour pressure of water present in environment and *vice versa*. The moisture content at the time when equilibrium is achieved by absorbing or losing moisture for specific temperature and relative humidity conditions is known as "Equilibrium Moisture Content (EMC)". The EMC plays significant role in drying and storage of food grains as well as dried fruit and vegetable products.

Objective

After studying and performing this experiment, you should be able to:

- determine the EMC (w.b.) of foods.

1.2 EXPERIMENT

1.2.1 Principle

When a moist food product is placed in a gaseous atmosphere containing water vapour, heat and water vapour exchanges occur between the two phases. The food absorbs or loses water to the atmosphere until a state of thermodynamic equilibrium is reached. Temperature and pressure are then constant and equal in both phases. The moisture achieved in this condition is EMC. In this experiment constant temperature is achieved using incubators and constant water vapour pressure of environment (relative humidity) at particular temperature is achieved using saturated salt solutions. The study is done in closed chamber in order to achieve constant relative humidity.

1.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/ Material)

- Hot air oven
- Moisture boxes
- Analytical balance (Least count 0.001 g)
- Desiccators

- Incubators
- Salts (NaCl, K_2CO_3, etc.), as per required humidity conditions

1.2.3 Procedure

- Set the incubator at a particular temperature.
- Place saturated salt solution, (particular salt which maintains a constant relative humidity at specific temperature), in the desiccators.

Table 1.1: Equilibrium relative humidities for some saturated salt solutions

Chemical	Relative humidity %		
	22·8°C	30°C	37.8°C
Sodium chloride	75.5	75.2	75.1
Sodium nitrite	64.8	63.3	61.8
Sodium dichromate	54.1	52.0	50.0
Potassium carbonate	43.9	43.5	43.4
Magnesium chloride	32.9	32.4	31.9

- Accurately measure moisture content of the test sample by drying in an hot air oven. Then keep the sample in Petri dishes, transfer the Petri dishes into desiccators, close the lid and keep the desiccators inside the incubator.
- Accurately weigh samples after 15 days, daily and observe the increase or decrease in weight till it becomes constant.

1.2.4 Observations

Parameters	16 day	17 day	18 day	19 day	20 day
Weight of Petri dish + equilibrated sample (w3)					

Let weight of empty Petri dish was (w1), weight of Petri dish + sample was w2, initially. Based on moisture content of initial sample, the weight of water present in the sample was W4, and then EMC will be given as

$$\text{EMC} = \frac{\text{Weight of sample after equilibration} - \text{Dry matter content of sample}}{\text{Weight of sample after equilibration}} \times 100$$

$$= \frac{(\text{w3} - \text{w1}) - (\text{w2} - \text{w1} - \text{W4})}{(\text{w3} - \text{w1})} \times 100$$

1.2.5 Results

Calculate EMC using above formula. The results are always displayed along with temperature and relative humidity.

1.3 PRECAUTIONS

- Never touch the sample or Petri dishes with wet hands.
- The Petri dishes should be dried before placing the samples.
- Sample should be evenly distributed inside the moisture boxes in a single layer.
- The Petri dishes should not come in contact with salt solutions.

EXPERIMENT 2 BULK DENSITY

Structure

2.1 INTRODUCTION

It is the weight of the food material in a unit volume. It is of importance in the packaging, handling and other operations.

Objective

After studying this experiment, you should be able to:

- determine the bulk density of the food material.

2.2 EXPERIMENT

2.2.1 Principle

The finely ground material is filled in a container of known volume, and its weight is measured. The mass per unit volume is bulk density. It should be in kg per cubic meter.

2.2.2 Requirements (Equipment/Machinery/Instrument and Chemicals/ Material)

- Measuring cylinder (250 ml capacity)
- Analytical balance (Least count 0.001 g)

2.2.3 Procedure

- Weigh a 250 ml capacity measuring cylinder (Say W1).
- Fill the pre-weighed measuring cylinder with finely ground vegetable/fruit sample (30-mesh size) up to the 100 ml mark.
- Weigh the filled cylinder with sample (Say W2).
- Repeat above steps with two more lots of the same sample.

2.2.4 Observations

Parameters	Sample number		
	1	2	3
Weight of empty cylinder (W1), g			
Weight of cylinder + sample (W2), g			

2.2.5 Results

Calculate bulk density using the formula given below. Take the average of three values and report the results in kg/m^3.

$$\text{Bulk Density} = (W2 - W1) \times 10$$

2.3 PRECAUTIONS

- Filling of the cylinder up to 100 ml mark should be accurate.

EXPERIMENT 3 TRUE DENSITY

Structure

3.1 INTRODUCTION

It is the actual volume occupied by the particles of food material. It is of the importance in the packaging, handling and other operations.

Objective

After studying this experiment, you should be able to:

- determine the true density of the food material.

3.2 EXPERIMENT

3.2.1 Principle

The material is filled in a container having a liquid already filled in it of known volume. The volume displaced by the sample particles is the true volume and ratio with its weight will give true density. It should be in kg per cubic meter.

3.2.2 Requirements (Equipment/Machinery/Instrument and Chemicals/ Material)

- Measuring cylinder (250 ml capacity)
- Analytical balance (Least count 0.001 g)
- Toluene

3.2.3 Procedure

- Accurately weigh a finely ground 100 g sample (W1).
- Now fill a 250 ml capacity measuring cylinder with toluene up to the 100 ml mark.
- Transfer the weighed sample into the liquid.
- Determine the change in volume (V1).
- Repeat above steps with two more lots of the same sample.

3.2.4 Observations

Parameters	Sample number		
	1	2	3
Weight of sample (W1), g			
Weight in the volume (V2), ml			

3.2.5 Results

Calculate true density using the formula given below. Take the average of three values and report the results in kg/m^3.

$$\text{True Density} = \frac{\text{W1}}{\text{V1}} \times 1000$$

3.3 PRECAUTIONS

- Filling of the cylinder up to 100 ml mark should be accurate.

EXPERIMENT 4 MEASUREMENT OF FAT/ OIL

Structure

4.1 INTRODUCTION

Fat or oil present in any food is the source of energy. The oils and fats are insoluble in water and soluble in some organic solvents. It may be present in the food material itself as in oilseeds or it may come during processing. Determination of fat / oil content is essential to know the calorific value of food.

Objective

After studying this experiment, you should be able to:

- determine the fat content of foods.

4.2 EXPERIMENT

4.2.1 Principle

Fats and oils are soluble in organic solvents like hexane, Isopropanol etc. but other constituents are not. Hence, the fat present in the food sample is dissolved into the solvent and afterwards solvent is removed by evaporation distillation (Boiling point of solvent is much less than that of oils/fat).

4.2.2 Requirements (Equipment/Machinery/Instrument and Chemicals/ Material)

- Soxhlet apparatus
- Extraction filter paper thimble
- Analytical balance (Least count 0.001 g)
- Sample grinder
- Organic solvent (Hexane, Isopropanol or diethyl ether), acetone

4.2.3 Procedure

- Thoroughly wash the boiling flasks and rinse with commercial grade acetone to remove any residual oil/fat.
- Dry the flasks by placing in hot air oven for 3-4 hours

- Weigh the flasks and label them.
- Weigh the extraction filter paper thimbles (in duplicate) and label them.
- Transfer 2-5 g samples in pre-weighed thimbles and determine their accurate weight.
- Plugged these thimbles with non-adsorbent cotton and place them straight in the soxhlet extraction tube.
- Fill the extraction tubes with solvent sufficient enough so that the siphon system starts working.
- Now fix the Soxhlet assembly properly and switch on the heaters.
- As soon as the initiation of boiling is indicated start the water connected to condensers and allow the extraction for 8 hours.
- After 8 hours switch off the heaters and allow cooling.
- The solvent is evaporated using vacuum oven at 50^{o}C or a water bath and then flasks with oil are weighed.

4.2.4 Observations

Parameters	Sample number		
	1	2	3
Weight of empty flask (w1)			
Weight of empty thimble (w2)			
Weight of thimble + sample (w3)			
Weight of flask + oil (w4)			

Fat / oil content is calculated by using the following formula.

$$\%\text{Fat / oil (w.b.)} = \frac{(w4 - w1)}{(w3 - w2)} \times 100$$

4.2.5 Results

Calculate oil/fat content using above formula. Take the average of three values and report the results as percentage.

4.3 PRECAUTIONS

- The water supply should not stop during the experiment. If so, the heaters should be put off.

- Take care that solvent should not come in contact with any heated surface as it is highly inflammable.

EXPERIMENT 5 CRUDE PROTEIN (TOTAL PROTEIN)

Structure

5.1 INTRODUCTION

Proteins are fundamental food components, both functionally and nutritionally. Dietary protein is supplied from plant and animal sources. Proteins are needed to build and repair body tissue and for the metabolic functions of our bodies. The crude protein is determined by estimating total nitrogen in any food material.

Objective

After studying this experiment, you should be able to:

- determine the total protein content of foods.

5.2 EXPERIMENT

5.2.1 Principle

Total nitrogen in all the samples is determined by the Kjeldahl method. It is a three step experiment as given below;

1. **Digestion:** It results in complete hydrolysis of the sample converting all protein and other nitrogenous compounds into ammonia.

2. **Distillation:** Distillation of the digested sample is the process during which the ammonia is released which is trapped in boric acid solution to yield ammonium borate.

3. **Titration:** The solution containing ammonium borate is titrated against 0.1 or 0.01 N HCI.

The protein content is estimated by multiplying % Nitrogen by a '**Protein factor'** as given below. In case factor is not known, 6.25 is commonly used.

Protein/product type	Protein factor
Egg	6.25
Milk	6.38
Meat	6.25
Rice	5.95
Barley	5.83
Wheat (whole)	5.83
Wheat (flour)	5.70
Maize	6.25

5.2.2 Requirements (Equipment/Machinery/Instrument and Chemicals/ Material)

- Conc. sulphuric acid
- Catalyst powder: Contains Cupric sulphate (penta-hydrate) and potassium sulphate (1:5 w/w).
- Sodium hydroxide solution (50%)
- Boric acid – indicator solution.

  Solution A: It is prepared by dissolving 40g boric acid in 1.95 litres hot distilled water.

  Solution B: It is prepared by dissolving 0.01 of bromo cresol green in 10ml of 95% ethyl alcohol.

  Solution C: It is prepared by dissolving 0.05 g methyl red in 50 ml of 95% ethyl alcohol.

  Finally solutions B and C are mixed and 50ml of this solution is made up to 2 litres with boric acid solution.

- Digestion assembly including Kjeldahl flasks / tubes.
- Distillation assembly
- Burette, pipette, conical flasks etc.

5.2.3 Procedure

1. Digestion of sample

- Accurately weigh 50 to 100mg sample (in duplicate) and transfer into two different Kjeldahl digestion tubes and label them.

- Add 4 ml conc. sulphuric acid and 100mg of catalyst powder to each digestion tube.

- Place the tubes on a heater to allow digestion at slow heat (100^{o}C) for 30 min. and gradually increase the temperature to 200^{o}C in about 1hour and finally to 420^{o}C until the colour of the content changes from dark brown to bluish green.

- The digested samples are then removed from heater and allowed to cool.

2. Distillation of sample

- Thoroughly clean the distillation unit and allow preheating.
- Now add 10 to 15 ml distilled water to each Kjeldahl tube/ flask.
- Close the stopcock and fill the reservoir with water to 2/3 its volume.
- Now transfer the diluted digested sample into the sample funnel and open the stopcock to allow the sample to drop into the mixing chamber.
- Rinse the Kjeldahl tubes with 10-15ml of distilled water and add the wash water to mixing chamber.
- Close the stopcock of the sample addition funnel and add sodium hydroxide (50%) solution to the sample funnel.
- Place the receiver conical flask containing 10 ml of boric acid with indicator with the outlet tube properly submerged into the solution.
- Now allow the sodium hydroxide solution to drop slowly into the mixing chamber by gently opening the valve of the sample addition funnel. Add 15-20ml of distilled water to the sample addition funnel and allow it to drop into the mixing funnel. Now close the sample addition funnel leaving some residual water in the funnel to work as water seal.
- Start heating of the content of the mixing chamber and continue for 20-30min, or until the colour of the indicator solution is changed from bluish purple to bluish green. Collected 15-20 ml of distillate.
- Finally slow down the heating intensity and gently remove the receiver flask while rinsing the outlet tube.

3. Titration

- Now titrate the distillate against 0.01 N HCl till the bluish green colour changes to pink.
- Run a blank preparation which has been identically prepared except that it does not contain the sample.

5.2.4 Observations

Parameters			
Sample titration value, ml			
Blank titration value, ml			

% Nitrogen is calculated as follows:

$$\%\text{Nitrogen} = \frac{(\text{Sample titre} - \text{Blank titre}) \times N \times 14 \times 100}{\text{mg of sample}}$$

N = Normality of HCl

% Crude protein = %Nitrogen × Protein factor.

5.2.5 Results

Calculate crude protein using above formula. Take the average of three values and report the crude protein content in percent.

5.3 PRECAUTIONS

- The digestion should be done in a closed cabinet so as to avoid inhalation of the fumes.

- During distillation, the outlet tube must be submerged into boric acid.

EXPERIMENT 7 FREE FATTY ACIDS (FFA)

Structure

7.1 INTRODUCTION

A small quantity of free fatty acids (FFA) is usually present in oil / fat along with the triglycerides. The content of FFA is known as acid number / acid value. It increases during storage of oil / fat as such or on oil/fat rich foods. Oil used for food purposes should have FFA level less than 1.5% as its keeping quality relies upon the FFA content.

Objective

After studying this experiment, you should be able to:

- determine the free fatty acid content of oil.

7.2 EXPERIMENT

7.2.1 Principle

The content of FFA in an oil is estimated by titrating it against KOH in the presence of phenolphthalein indicator. The acid number is defined as the amount (in mg) of KOH required neutralizing the free fatty acids in 1g of oil sample.

7.2.2 Requirements (Equipment/Machinery/Instrument and Chemicals/ Material)

- Solvent (Mix 100ml of 95% aqueous ethyl alcohol with 100ml of diethyl ether. Neutralize the solvent with 0.1N using phenolphthalein indicator).
- Potassium hydroxide, 0.1N
- Indicator dye (Dissolve 500mg phenolphthalein in 50ml 95% ethyl alcohol)
- Water bath
- Analytical balance

7.2.3 Procedure

- Transfer 10g accurately weighed sample of oil into 250ml Erlenmeyer flask and add 50 ml of neutralized solvent. Add a few drops of phenolphthalein indicator.
- Keep in water bath at 50°C for 15min with continuous agitation.
- When the content is properly mixed titrate the content against 0.1 KOH until the appearing pink colour persists for 15 sec.

7.2.4 Observations

Parameters	**Sample number**		
	1	**2**	**3**
Titre value, ml			

7.2.5 Results

Calculate FFA content in terms of acid value using the formula given below. Take the average of three values and report the results.

$$\text{Acid value} = \frac{\text{Titre value} \times \text{Normality} \times 56.1 \text{ of KOH}}{\text{Weight of the sample (g)}}$$

7.3 PRECAUTIONS

- Continuous agitation is required while titrating.

UNIT 1 IMPORTANCE OF POST HARVEST MANAGEMENT

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- understand how post harvest management can reduce losses after harvest and increase food availability thereby provides food and nutritional securities;
- state proper post harvest care can add value and provide benefit to the producers and consumers;
- explain efficient post harvest operation can generate employment and bring rural industrialization;
- highlight the role of post harvest technology for better economy of the country through export earning; and
- demonstrate how appropriate post harvest management and processing can utilise unmarketable produce and processing waste for gainful purpose hence reducing pollution and city garbage.

1.1 INTRODUCTION

India is a vast country and a wide range of variety of fruits and vegetables are cultivated in different regions. There has been a phenomenal rise in production of fruits and vegetables in our country since Independence. As per the data for 2000-2001, the production of fruit is about 45.37 million metric tonnes and vegetable about 93.92 million metric tonnes available in India and going to be doubled by 2011 and is considered to be the second largest producer next to china in the world. Unfortunately, unlike other horticulture rich countries, average Indians do not get the basic daily requirement of fruits and vegetables and our Human Development Index is very low. This is because a considerable amount of this valuable produce is lost due to improper post harvest management. High moisture content, living nature and presence of readily utilizable nutrients make fruits and vegetables highly perishable commodities.

Spoilage mainly occurs due to microbial attack, auto-oxidation and insect pest attack. According to a study, at least 25 to 30 percent of the production of fruits and vegetables in the country is lost due to wastage and value destruction. The wastage cost was estimated to be Rs. 67,500 crores each year. Even if 1% of this could be saved by converting them into value added products, there will be a saving of Rs. 67.5 crores annually. Further, the cost of reducing spoilage is much lesser than the production of the same quantity and quality produce. Post harvest management of horticultural produce is therefore the need of the hour in order to feed ever-growing population of the world in general and India in particular. The most important advantage of post harvest management and processing is the reduction of post harvest losses of fruits and vegetables.

1.2 INCREASE FOOD AVAILABILITY

It is well known fact that fruits and vegetables are perishable in nature due to its high moisture content, high rate of physiological activity viz. respiration and ripening, microbial attack, rapid bio-chemical changes such as enzyme activity, softening of the texture and many other biotic and abiotic factors. Harvesting season of almost all fruits and vegetables is very narrow lasting only for 1-2 months. During this short period, availability of that particular fruits and vegetables is abundant but at the end of harvesting season, products availability decreases rapidly and may be completely out of market within 1-2 months. Here, therefore comes the role of Post harvest management of horticultural commodities like proper handling, packaging and storage at safe low temperature, maintenance of cool chain during transportation and marketing, pre and post harvest treatments in order to increase self - life and reduce the overall spoilage etc. These practices make fruits and vegetable available through out the year. Many modern technologies such as refrigerated storage and transportation, Controlled and Modified storage, irradiation, processing into value added products are some of the ways to extend the availability of fruits and vegetables beyond the end of the harvesting season. In this way, the food already produced can be saved for consumption by applying the techniques of post harvest management and indirectly increase food availability. Attention to the concept of post-harvest food loss reduction as a significant means to increase food availability was drawn by the World Food Conference held in Rome in 1974. The seventh session of the U.N. General Assembly in 1975 passed a resolution calling for a 50 percent reduction of post harvest losses by 1985. In the FAO, after consultation with its Governing Body food loss prevention became a priority area and an Action Programme became operational in early 1978. The Food Loss Prevention Programme of FAO till recently focussed mainly on the durable food grains, because of the prominence in daily diet. Only in May 1980, an Expert Consultation on Food Loss Prevention in Perishable Crops mainly covering fruit and vegetables was held in Rome.

1.3 NUTRITIONAL SECURITY

Fruits and vegetables constitute an important part of human's food. Even though they are generally not considered as a staple food yet they help in intake of cereal foods by making them more palatable in nature. Fruit and Vegetables in general, except for a few, are not considered to be the primary source of carbohydrate, protein and fat. However, some of them with storage roots and tubers are rich in carbohydrate, particularly starch, in amounts comparable to the cereal crops, and the leguminous vegetables supply as much as 14 per cent protein, dry seeds supplying still more. The lipid content in most vegetables is less than 0.1 per cent. Most fruit, vegetables and root crops are rich in minerals, carotene (Pro-vitamin A) and vitamin C. Besides, there are some trace elements required by the body like copper, manganese and zinc, which act as coenzymes. These are found in appreciable quantity in fruit and vegetables. The amount of nutrient can vary with fruit and vegetables, cultural practices, stage of maturity, post-harvest handling and storage conditions. Once they are harvested, their composition goes on changing as a result of physiological and biochemical activities, which are natural processes. Fruits and vegetables are the rich source of vitamins, minerals, and trace elements, deficiency of which leads many diseases such as scurvy, beriberi, night blindness etc. In addition, most of the fruits and vegetables are also loaded with antioxidants and fibers. Antioxidant neutralizes free radicals produced in the body that is found a possible cause of cancer and also prevents faster aging. At the same time fiber controls many cardiovascular diseases and movement of foods in the digestive system. Several vitamins and minerals that are scarce in cereals and animal products are present in abundance in fruits and vegetables. Beside this, fruits and vegetables also supply carbohydrates and protein and fulfill the essential nutrients in human diet. Therefore, human health is protected if fruits and vegetables or their processed products are consumed regularly. Fruits and vegetables are therefore considered as protective foods. Further, several vitamins, minerals and phyto-hormones found in fruits and vegetables have now assumed the status of functional food. These substances are capable of providing additional physiological benefit, such as prevention or delaying onset of chronic diseases, as well as meeting nutritional requirements. Keeping in view the nutritional quality of fruits and vegetables, post harvest management of these perishable commodities is the only solution for nutritional security to ever growing population of the country.

1.4 EMPLOYMENT GENERATION

Employment generation of Indian Youth is becoming more and more difficult with increasing in population. It has been observed that job opportunities in government sectors are shrinking day by day and private companies closing fresh recruitment. For rural youth, it becomes more and more difficult to get a good or moderate employment in rural areas as a result unemployed rural youth are rushing towards towns and cities to do any sort of work. This type migration of population from rural to urban area is detrimental to the society. In addition, this situation is creating a big problem in metro cities. Therefore it is the need of the hour that these youth start their own ventures that should not only be remunerative and attractive in nature but also easy to operate. Post harvest handling and processing of fruits and vegetables is one such area that can provide great possibility for employment generation. During harvesting season, people can get employment in harvesting, pre-treatments if any, packaging and transportation of fresh produce to towns and cities. The surplus production and cull fruits and vegetables can be converted into pulps and value added products during the season and later it can be used to prepare various tertiary processed products. All these operations require human resources in large quantity.

A fruit and vegetable processing factory having a capacity of 10qt/month can engage 4-6 people for the whole year. In addition in order to handle freshly produced fruits and vegetables properly grading and packing stations and quality control laboratory have to be developed to keep the pace of development process. Further, as ancillary industries manufacturing units for food processing machinery, packaging materials both for fresh and processed fruit and vegetable products will also develop side by side and generate employment. Other relevant industries and establishments, such as, retail outlets etc, will also provide additional employment. In our country 90% of fruit and vegetable produced are marketed by the farmers compared to only 20% of cereals/food grains production of India.

Employment potential of food processing industries is much higher compared to many other relevant industries. For example per 1,000 crores of investment employment potential in food is 54,000 compared to textiles –48000 and paper –2500. It has been reported that there is a 4 fold indirect employment on investment in food and it provides 60% employment in small towns and rural areas. Our aim is to increase processing from present level of 2% to 10% by 2010 that will involve an investment of Rs.1,40,000 crores generating direct employment 77 lakh and indirect employment 3 crores.

1.5 VALUE ADDITION

Horticultural produce in general and fruits and vegetables in particular generate a large amount of valuable waste such as inedible plant parts as such for human food that end up as garbage. However, if they are gainfully utilised at the proper time they can produce value added products. Vegetables such as cauliflower, peas, leafy vegetables, etc. can be primarily/minimally processed so that inedible parts are removed before being sent on to the metropolitan city markets. They should be unit packed at packing stations situated at appropriate points in every district. This process will reduce the transportation and handling cost of inedible parts and help the consumer by providing a convenience food. The consumers particularly the working women would be willing to pay higher prices because these ready to use products save lots of time, in kitchen besides labour and space. Similarly, bananas should be transported in hands as is done in other countries. Each packing station should have the facility for processing. Physically damaged fruit and vegetables that are without infection but would be spoiled on storage can be made into durable and value added processed products at this point. Utilization of physically damaged fruits and vegetables into value added processed product could considerably reduce the price of main product as a result more processed food products will come within the reach of common people.

Fruits and vegetables are perishable in nature, it can not be stored for longer period. It has been observed that about 25-30% of total production are not fit for fresh marketing and called culled produce. These produce are undersized, oversized and malformed/deformed and physically damaged fruits and vegetables but microbiologically sound at the time of harvest. The produce of this category either sold at throw away prices or left to spoil as such. Thus a huge quantity of horticultural produce in the form of cull fruits and vegetables occurs every year which otherwise could be utilized, if processed into various value added by products. Fruits and vegetable processing units also generate large amount of valuable waste such as peel, stones and other inedible plant parts that are generally not utilsed properly and rejected as such in our country and finally end up as garbage. However, if they are gainfully utilised at the proper time they can become value added products. Some of theses waste are rich source of vital constituents like carbohydrates, protein, fat, minerals, edible fibres, etc. and also constituents of commercial use such as pectin, starch, colours/ pigments, essential oils, sugars, vinegar, alcohol, and many compounds useful in food and beverage industries. In addition the waste may be used as cattle feed that is in short supply in our country. These waste processing not only gives value added products but also reduce the price of the primary processed products that are sold at a premium price in our country beyond the means of the common people. In general, it improves the overall economy of the country. Premature fruit drop due vagaries of climate such dust or hailstorm is also a big problem in India. As a result a substantial quantity of fruits and vegetables are lost before they attend proper maturity stage. These produce can be utilized usefully if processed into value added products such as pulp, pickle, chutney, dried powder etc.

During peak harvesting season a good amount of quality fruits and vegetables are available in abundant quantity resulting in market glut and all of these quality produce can not be marketed in the fresh form. As a result, there is huge spoilage and wastage of fresh fruits and vegetables. This wastage can be reduced if they are timely processed into different value added products or preserved by different methods during harvesting season. Now it can be used throughout the year and can be transported to distant market. Value added products not only palatable but also nutritious and gives economic gain. Nutritional value of these products can be increased many folds through fortification particularly of protein, vitamins and minerals. Processing serves as an outlet for surplus production and therefore acts as price stabilizer. Fruits are generally consumed as fresh but mostly vegetables are cooked before consumption expecting a few ones like cucumbers, tomatoes etc. Value addition also includes peeling, slicing, cutting into pieces, processing and packaging. All such activities increase value of the products.

India has a wide range of indigenous fruits that are underutilized. Most of these fruits are tropical/subtropical in nature and grow even under adverse agro-climatic conditions. A large number of these fruits are known for their therapeutic/medicinal and nutritive value and have excellent flavour and very attractive colour. Some of these fruits are not easy to eat out of hand e.g. baelfruit that has a hard shell, mucilaginous texture and numerous seeds; as a result it is not popular as a dessert fruit. Kokum is not acceptable as a fresh fruit because of its high acidity, only its thick outer rind is used in beverage industry or for culinary purpose in the dried form. Similarly aonla as a fresh fruit is not liked because of its strong astringent taste. All these fruits have a great potentiality to processing into a value added fruit products of commercial importance. So that the growers get a remunerative price and consumers get the opportunity to enjoy the indigenous fruit products. A shrink-wrapped fruit and vegetable fetches more prices compared to non shrink-wrapped ones because of value addition.

It has already been mentioned that less than 2% of production of fruits and vegetables in India goes for processing. As a result, value addition in food sector is low at 7%. The production of fruits and vegetables in our country is now 66% of food grains. It is expected that this figure is likely to be 80% by 2010. With proper infrastructure facility for post harvest handling and processing, value addition will correspondingly go up from 7% to 35 % resulting in increases in GNP.

1.6 EXPORT EARNING

It is known that about 84 different fruits and 63 items of vegetables are traded in world market. In addition a large number of fruit and vegetable products are also marketed. India by virtue of its varied agro-climatic conditions has the advantage of producing most these fruits and vegetables and processing them into products that can be traded in the world market. In order to achieve export potential, following fruits have been identified as having good market potential viz. Mango, Grapes, Banana, Lychee, Exotic fruits Chikoo, Ber, Pomegranate, Amongst vegetables the items identified as having good export potential are - Onion, Potato, Green vegetables. The following two categories of vegetables also has great potentiality: a) Traditional - okra, bitter gourd, chili and other seasonal vegetables; b) Non-traditional - asparagus, celery, broccoli, bell pepper, sweet corn and baby corn; green and lima beans.

India has vast resources of indigenous fruits and vegetables that have established medicinal and therapeutic values apart having high nutritive value, attractive color and excellent flavor viz. aonla, baelfruit, jamun, kokum, phalsa etc. There is always a demand all over the world for new, nutritious, attractive and delicately flavoured products. Also, the trend today is a return to the natural and a preference for the therapy provided by nature. Consumers today are becoming increasingly conscious of the health and nutritional aspects of their food. The tendency is to avoid chemicals and synthetic foods and choose therapy and nutrition through natural resources. The underutilised fruits of India have an important role to play in satisfying the demand for nutritious, delicately flavored and attractive natural foods of high therapeutic value. The development of these fruits can considerably contribute to crop diversification, farm income and the improvement of nutrition and also provide valuable exports and additional employment. Therefore, among these indigenous fruit lies an untapped potentiality for processing into value added products that can attract export market. For example, Bael and Aonla are indigenous fruits having highest riboflavin (Vit. B2) and vitamin C respectively. Increased health consciousness in the masses will boost their consumption in India and in International market. Any Aonla products can be exported as they are rich in vitamin- C. Therefore, export of these indigenous fruits and vegetables and their processed products can earn valuable foreign exchange. Though some fruit products, are being manufactured at present on a small scale, inspite of such favourable possibilities no systematic approach has been made to utilise the potential of the indigenous fruits on a large scale mainly because of the lack of the requisite amount of raw material. Organised orcharding and systematic collection of raw material is of utmost importance. Kiwi fruit that was practically unknown in the world market a few years back, is now in the forefront of international fruit trade. The New Zealand Kiwi Fruit Marketing Board highlighted the plus points of Kiwi Fruit such as thirst quenching, highly nutritious, rich in Vitamin -C, good for maintaining health, slimming effect etc. to make it popular among the consumers the world over. There is no reason why we can not achieve similar success. Instead of trying to compete in a market where other countries are already established and far ahead we must break new ground and create markets for our indigenous fruits where no other country can compete with us.

Freezing is rated as the best technique available for food preservation since it maintains the natural properties by reducing post harvest changes and microbial deterioration to the barest minimum without any influence on the original qualities. The rate of freezing plays a great role on the quality of frozen fruits and vegetables; faster freezing rate is required to obtain better quality. Liquid nitrogen is the most common cryogenic substance fused in food freezing. Ultra quick freezing rate, minimum dehydration less, freedom from oxidative changes, minimum freezing damage of freeze sensitive products, maximum quality retention of texture, colour and flavour of sensitive fruits and vegetables during freezing and the inert nature of the freezant are the advantages of liquid nitrogen freezing. A systematic establishment of quick freezing industry can boost export trade of our country. Methods have been standardized under laboratory conditions for the manufacture of cryogenically frozen, crack free, peeled ripe mango slices having excellent retention of quality attributes, well comparable with those of fresh mangoes in ready-to-serve form and cent-per-cent edible portion. This will have a great potentiality in export trade. The problems generally facing the export of fresh mangoes, like short storage life, added bulk of stone and peel, hidden disorders like spongy tissue and stone weevil can be successfully overcome by producing the cryogenically frozen mango slices.

Hardly there is any fruit that is not cultivated in this country. At present only few established fruits and vegetables are exported. Government has already recognized it as one of the major thrust for augmenting the countries export. Lack of proper post harvest management and infrastructure facilities are the major hurdles for export of horticultural produce. Countries like Indonesia, Malaysia, Thailand etc. are far behind in production of fruits and vegetables compared to India but their exports are many folds higher than our country. It is mainly because of good post harvest management practices, quality maintenance through out the marketing channel and basic infrastructure for export

1.7 RURAL INDUSTRIALISATION

Post harvest management and processing of fruits and vegetables is the backbone of the horticulture industry as it takes care of gluts and all possible wastage that occur during handling, storage, distribution and marketing. Most growers are rural people. During peak harvesting season, always there is glut. There is no preservation unit, grading and packinghouse in rural areas. They can not hold their produce, even for few days due to lack of storage facility and they are unable to preserve their produce. This situation forced them to sale their good quality produce at very low price to middleman. Cull fruits and vegetables are generally goes waste or sold at a throw away price. After harvesting season is over, again rural people become jobless. They generally migrate to cities in search of any sort of job. Setting up of small and cottage level preservation factory at village level not only reduces losses due to glut but also provides jobs for rural people. It can always fetch an additional income to the grower and help in stabilizing the prices and providing economic return. Hence, fruit and vegetable processing industry should be encouraged and developed in rural areas, a way of rural industrialisation

1.8 BENEFICIAL TO PRODUCERS AND CONSUMERS

In a country like India, transportation facilities are not so good, rural electrification is also in infancy stage and huge production of horticultural produce occur in different parts of the country particularly in the rural areas and under developed areas. There is always abundance of produce at the production site but scarcity of the same produce at consumption places.

Growers at production site sale their produce at the lowest minimum price due to fear of spoilage. However, the consumers purchase the same commodities at a very high price in cities and urban areas due to involvement of middle man. In this way, both producers and consumers suffer and middle man only get advantage. To overcome this situation, growers should be trained properly about post harvest management, storage and processing of fresh Fruits and vegetables. There must be on farm storage facilities viz. pusa zero energy cool chamber for short duration storage. Cottage and small scale level fruit and vegetable processing unit must be encouraged so that cull fruits and Fruits and vegetables can be converted into value added products, properly stored and processed products can be transported to the places of scarcity during their harvesting season and after the season is over. In this way a glut like situation can be avoided in production areas. Growers will get a good price for their produce and consumer will have to pay a reasonable price only.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the major factors responsible for spoilage of fruits and vegetables?

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2. How post harvest management of fruits and vegetables can increase food availability?

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3. How fruits and vegetables processing industry can revive rural industrialization?

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4. What are the importance and advantages of value addition?

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5. How do you increase export of fresh and processed fruits and vegetables?

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6. Why fruits and vegetables are called as protective foods?

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1.9 LET US SUM UP

Fruits and vegetables are highly perishable in nature that results in rapid spoilage and deterioration in quality. However, proper post harvest management can reduce this spoilage. The cost of reducing spoilage is much lesser than the production on additional land. A good post harvest management reduces spoilage by preserving seasonal surplus and cull fruits and vegetables, which often lie rotting on the roadside. Processing and value addition increases food availability, generates cattle feed by converting factory waste thus reduces garbage accumulation. Growers get remunerative price of their produce and consumers buy it at reasonable price. Many indigenous fruits and vegetables, which are not generally marketed, as fresh can be processed into value added products for export. These products are in demand in national and international market due to its medicinal and therapeutic properties. Fresh as well as processed fruits and vegetables is rich source of vital nutrients like vitamins, minerals, fibers etc. It gives nutritional security forever growing population and protects their health.

1.10 KEY WORDS

Post harvest management : Methods and techniques applied to increase the shelf life and retain quality of horticultural

		produce either as fresh or processed into different products.
Post harvest losses	:	Losses of horticultural commodities in quality and quantity after harvesting till consumption.
Food availability	:	Availability of fruits, vegetables and their processed products beyond their harvesting season or round the year.
Irradiation	:	Exposure of biological materials to radiation such as X-ray, gama-ray, electron beams etc.
Antioxidants	:	Substances which prevent oxidative reaction in foods.

1.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - High moisture content.
   - More physiologically active.
   - Soft texture and rich nutrients invites microbes and insect pest.
   - Susceptible to rapid enzymatic oxidation.

2. Your answer should include the following points:

   - Post harvest losses reduction at different stages increases food availability.
   - Processing of surplus fruits and vegetables into value added products.
   - Utilization of cull fruits and vegetables into processed products.
   - Increases shelf-life of fruits and vegetables by improved post harvest management.

3. Your answer should include the following points:

   - Fruits and vegetables processing industry utilizes surplus and cull produce.
   - It provides more employment and occupation for rural people.
   - It saves farmers from distress selling.
   - Ideal in rural areas due to cheap availability of raw material and local labour.

4. Your answer should include the following points:

   - Indigenous fruits and vegetables having medicinal and therapeutic properties.

   - Cull and surplus produce can be utilized for preparation of various products instead of throwing for spoilage.

   - Waste generated during processing can be processed either into animal feed or for use in related industry.

- It generates employment, animal feed and prevents garbage accumulation.
- Earns valuable foreign currency and saves Indian currency paid for import of processed fruits and vegetables products.
- Fulfills Defense requirements.
- Improves overall Indian economy.

5. Your answer should include the following points:
   - Better post harvest infrastructure for export purpose.
   - High tech processing like cryogenic freezing and aseptic packaging.
   - Fresh vegetables rich in anti-oxidant medicinal value.
   - Processing of indigenous tropical fruits rich in nutrient and therapeutic value.

6. Your answer should include the following points:
   - Fruits and vegetables are rich source of vitamins which prevents diseases like scurvy, Beriberi, night blindness etc.
   - They are also rich source of antioxidants neutralizes free radicals formed in human body that causes sometimes cancer and accelerates faster aging.
   - Minerals found in fruits and vegetables take part in various biochemical reactions.

1.12 SOME USEFUL BOOKS

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UNIT 2 CAUSES OF PRE AND POST HARVEST LOSSES OF FRUITS AND VEGETABLES

Structure

2.0 OBJECTIVES

In this unit we will discuss the pre- and post-harvest factors for post-harvest losses of fruits and vegetables.

After going through this unit, you should be able to know the:

- role of cultural practices (irrigation, nutrient deficiency) and maturity index in post-harvest losses of fruits and vegetables;

- infestation of pest and disease and their contribution to post-harvest losses;
- role of environmental factors such as soil condition, climate, frost, hail, pollutants etc. in post-harvest losses; and
- improper handling, storage, transportation and socio-economic factors and their impact in post-harvest losses.

2.1 INTRODUCTION

Fruits and vegetables not only provide nutritional security, but also generate a high income to growers. Better production practices, careful harvesting and proper packaging, storage and transport contribute to the good quality produce. Once a crop is harvested it is impossible to improve its quality. Because of high moisture content, fruits and vegetables are inherently more liable to deteriorate. After harvest, they are also biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which deteriorate the quality of the produce. In India, the post harvest losses of fruits and vegetables is varying from 25-40% /depending upon the kind of produce and its pre and post-harvest practice. This can occur in the field, in packing houses, in storage, during transportation and in the wholesale and retail markets. Severe losses occur because of poor infrastructure, poor pre and post harvest management, marketing of the produce.

Biological causes of deterioration of fruits and vegetables include metabolic changes (respiration, ethylene production and action, compositional changes), mechanical injuries (cuts, bruises, abrasions, etc.), incidence of physiological disorders, and pathological breakdown. The rate of biological deterioration depends on various environmental factors including temperature, relative humidity, and concentrations of ethylene, oxygen, and carbon dioxide.

The loss in food value of fruits and vegetables may be attributed after harvesting through several ways:

- Water content is reduced with time as the continuation of living processes within the produce and as result the commodity gets shrivelled and loses its turgidity.
- Vitamin C content decreases with time after harvest.
- Cooking partially destroys water soluble vitamins B and C.
- Peeling may cause significant loss of food value, since most of the nutrients are in engrossed in epidermis skin especially in potatoes, where the protein content is just adhering to skin.
- Water used in cooking vegetables dissolved minerals and trace elements.

2.2 PRE-HARVEST FACTORS IN POST HARVEST LOSSES

2.2.1 Choice of Cultivars and Planting Materials

The healthy crops will only come from healthy and good quality planting materials. The market quality of the produce is determined by selecting the crops, their cultivars, and the production system. It is well known that some cultivars have better palatability apart from better transport quality and longer shelf life than others. While selecting planting materials following points should be taken into consideration.

What Needs to Do?

- Choose cultivars that will have better quality attributes and as per the demand of the consumers.
- Use clean, healthy, high quality planting materials.
- Grow off-season cultivars of the same crop to extend harvest period.
- Choose cultivars that are well suited to the specific climate, day length, soil and growing conditions.
- Always select seed from the good quality produce or source.

2.2.2 Cultural Practices

Cultural practices can also affect post-harvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (scrapes, bruises, abrasions) is particularly susceptible to post-harvest diseases. For example, mold and decay on pumpkin and squashes caused by the fungus *Rhizoctonia* results from the fruits lying on the ground. Cauliflower curds are susceptible to post-harvest rot caused by the bacteria *Erwinia* if nitrogen is applied as foliar spray. Beets and radishes are susceptible to soil-borne diseases when the soil temperature reaches 80º F. The finger rot in banana and stem end rot in mango caused by *Botryodploidia theobromae* is more severe when temperature is above 30^0C and 20^0 C and bow the growth of the fungus is poor.

Several diseases outbreaks in the field may cause food borne illnesses which have been traced to contamination of produce in the field.

What Measures to Take?

- Follow only recommended practices in terms of variety, season its manure/fertilize doses, irrigation level and the care during growing and after harvesting.

2.2.3 Irrigation

Growing plants need a continuous water supply for both photosynthesis (the process by which plants convert light to chemical energy and produce carbohydrates from carbon dioxide and water) and transpiration (the giving off by a plant of vapour containing waste products). If banana is allowed to mature fully before harvest and harvesting is shortly after rainfall or irrigation, the fruit can easily split during handling operations, allowing micro-organism infection and post-harvest rotting.

Bad effects can be caused by:

- The use of irrigation methods that spray water on foliage or excessive rainfall can increase incidence of disease and fungal infections.
- Excess rain or irrigation during growing and before harvesting can contribute to loss of flavour in many crops and increased susceptibility to bruising and decay in storage, respectively.
- Lack of rain or irrigation during growing can cause low juice content and thick skin in citrus fruit.

- Dry conditions followed by rain or irrigation, give rise to growth cracks or secondary growth in potatoes and growth cracks in tomatoes.

Judicious application of water during the maturity will reduce the post-harvest losses of fruits and vegetables.

2.2.4 Nutrient/Mineral Deficiency

Lack of plant nutrients in the soil can seriously affect the quality of fresh produce at harvest. On the other hand, too much fertilizer can harm the development and post-harvest condition of produce. Crops which contain high levels of nitrogen have poorer keeping quality than the same variety of crop with lower nitrogen levels. The problem of fertilizer balance in soils and its effect on crops is complex and depends also on other conditions such as temperature, moisture, acidity of the soil and reactions among different fertilizer chemicals. Imbalance of fertilizers can result in several physiological disorders which alter the appearance and ultimately consumer's acceptance of the fruit and vegetable produce during post-harvest period.

Nutrient deficiency	Physiological disorder
Calcium	blossom end rot in tomato and capsicum, internal browning in Brussels sprout, internal tip burn in cabbage, cavity spot and cracking in carrot, black heart in celery, hollow stem in cabbage, cauliflower and Brussels sprouts, bitter pit in apples, calyx en rot in persimmon, leaf drop in peach etc.
Boron	cracked stem in celery, root split in carrot, brown heart or root canker in beet, browning of curd in cauliflower, lumpiness in papaya, internal necrosis in mango, fruit cracking in pomegranate, russeting and internal cork in apple etc.
Molybdenum	whiptail in cauliflower, yellow spot diseases in oranges
Manganese	marsh spot in peas and beans
Nitrogen	stunted growth or yellow-red discoloration of leaves in green vegetables
Magnesium	Interveinal chlorosis in apple

2.2.5 Other Cultural Practices

- Pruning and thinning – improves sun penetration and ventilation which is important for uniform fruit colour development, increase in fruit size and quality, but yield decreases slightly. Encouraging plants to grow upward on trellises also lowers relative humidity and reduces incidence of disease.

- Weed control – weeds are commonly alternative hosts for crop diseases and pests. Weeds also compete with crops for nutrients and soil moisture and thereby reduce the quality of fruits and vegetables.

- Crop hygiene – decaying plant residues, dead wood and fruit and vegetables wastes are all reservoirs of infection causing post-harvest decay. Their collection and removal are important to keep your crop safe from bacterial and fungal infection.
- Use cultivation practices that are recommended and appropriate for the region and climate.
- Pesticides and herbicides can damage by causing spray burns and leave poisonous residues if used incorrectly.
- Growth-regulating chemicals are used mainly to improve marketability of fruit by controlling the time of fruit set and promote uniform ripening. They require specialist knowledge.

2.2.6 Improper Harvesting

A critical time for growers of fruit and vegetables is the period of decision on when to harvest a crop. Normally fruits and vegetables are harvested when they have developed to the ideal condition for consumption. This condition is usually referred to as harvest maturity. Confusion may arise because of the word maturity since, in the botanical sense, this refers to the time when the plant has completed its active growth (vegetative growth) and arrived at the stage of flowering and seed production (physiological maturity).

Maturity whether viewed as physiological maturity or harvestable maturity can have a pronounced influence on the quality of fruits and vegetables. Optimum maturity at harvest depends on the market or intended use (storage, fresh consumption and processing). For many vegetables the optimum eating quality is reached at tender stage e.g. leafy vegetables, cucumber, bottle gourd, green peas, beans, okra etc. Delayed harvest will lead to fibre development. The good quality fruits are obtained when harvesting is done at proper stage of maturity. Immature fruits when harvested will give poor quality and erratic ripening. For example the fruits of mango are harvested based on fullness of cheeks, colour in pedicel end whereas banana fruits are harvested based on fullness of fingers and disappearance of angularity on the surface.

Method of harvesting is as important as time of harvesting. Faulty harvesting and rough handling at the farm directly affect market quality. Injury to peel may serve as entry port for the micro-organisms and lead to rotting. For example, banana bunches should be cut leaving 30 cm of stalk.

2.2.7 Post-harvest Physiology

The quality of the harvested fruits and vegetables depend on the condition of growth as well as physiological and biochemical changes they undergo after harvest. Fruit and vegetable cells are still alive after harvest and continue their physiological activity. The post harvest quality and storage life of fruits appear to be controlled by the maturity. If the fruits are harvested at a proper stage of maturity, the quality of the fruits shall be good. Poor quality and uneven ripening are due to early and late harvesting may result in extremely poor shelf life.

Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavour, loss of saleable weight, and more rapid deterioration. The respiration rate of a commodity strongly determines its transit and post-harvest life. The higher the storage temperature, the higher the respiration rate will be.

Respiration plays a very significant role in the post harvest life of the fruits. In most of the fruits, the rate of respiration increases rapidly with ripening. The sudden upsurge in respiration is called the 'climacteric rise', which is considered to be the turning point in the life of the fruit. After this the senescence and deterioration of the fruit begin.

Climacteric fruits	**Non-climacteric fruits**
Apple, banana, papaya, mango, guava, jackfruit, fig, sapota, tomato, musk melon, water melon etc.	Litchi, pineapple, grapes, pomegranate, lemon, orange, lime, cucumber etc.

To extend the post harvest life of the fruits its respiration rate should be reduced as far as possible. Thus an understanding of the factors, which influence the rate of respiration, is indispensable to post harvest technologies for manipulating the storage behaviour of fruits and vegetables.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Match the following:

Nutrient deficiency	**Physiological disorder**
(a) Calcium deficiency	i) marsh spot in peas and beans
(b) Boron deficiency	ii) Inter-veinal chlorosis in apple
(c) Molybdenum deficiency	iii) browning of curd in cauliflower
(d) Manganese deficiency	iv) whiptail in cauliflower
(e) Magnesium deficiency	v) bitter pit in apples

(a)	
(b)	
(c)	
(d)	
(e)	

2. Critically analyse the role of cultural practices in post harvest losses of fruits and vegetables with suitable examples.

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3. Write few basic criteria for selecting cultivars/planting materials for quality produce?

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4. What do you mean by climacteric and non-climacteric fruits?

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2.3 BIOLOGICAL FACTORS

Heavy post-harvest losses are occurred by the invasion of fungi, bacteria, insects and other organisms. Microorganisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defense mechanism after the harvest and has plenty of nutrients and moisture to support microbial growth. Almost all post-harvest pests originate from field infestations, and if the storage condition is conducive they can multiply on.

2.3.1 Pathological

Plant pathogens cause substantial losses of fruits and vegetables during production. Specific pathogens also resulted in undesirable post-harvest losses. For example, bacterial spots in tomato caused by *Xanthomonas campestris* pv vesicatoria; white mould *(Sclerotinia sclerotiarum)* produces white mycelium in blossom end of cucurbits.

Viral disease like Zucchini Yellow Mosaic virus of summer squash *(Cucurbita pepo)* resulted small distorted fruit and tomato mosaic virus causes discolouration of mature tomato fruits. Black mould rot caused by *Aspergillus niger,* bulb rot by *Fusarium solani* and bacterial rot by *Pseudomonas* sp. infection during cultivation of onion may cause damage during storage. Preharvest infection of fungi, *Botryodiploidia theobromae* and *Glomerella cingulata* cause stem end rot and anthracnose disease, respectively, in mango which usually develop as the fruits ripen. These diseases are also to be effectively controlled before harvest otherwise act as inoculums for post harvest loss.

2.3.2 Entomological

Feeding by different insect generally resulted in distinctly undesirable appearance of the produce. For example, cabbage loopper *(Trichoplusia nii)* create holes in foliage and head becomes unacceptable. Some insects cause primary damage by developing larva that tunnel throughout interior portion of the produce as sweet potato weevil, *Cylas formicarius*. Another form of damage produced through lack of or incomplete pollination resulting in misshapen fruits. For example, cucurbits exhibit small, distorted fruits that are generally shed before reaching harvestable maturity when pollination is inadequate. In the fruits of mango, the insects like fruit flies (*Bactrocera dorsalis*) and mango stone weevil (*Sternochetus mangiferae*) those invaded at the time of flowering, remained inside the fruits till the ripening of fruits. These fruits are unfit for consumption and cause the damage even during storage.

2.4 ENVIRONMENTAL FACTORS

The environmental factors such as soil type, temperature, frost, and rainy weather during growing and at harvest can have an adverse effect on storage life and quality. For example, carrots grown on muck soils do not hold up as well in storage as compared to carrots grown on lighter, upland soils.

2.4.1 Climate

Temperature during growth affects cucumber fruit length and thus repressing development. Likewise, cucumber fruit curvature is increased with increasing temperature. High temperature during pollination resulted in puffiness of fruit in tomato.

2.4.2 Chilling Injury

Chilling injury is often associated with storage but it also occurs prior to harvest. In sweet potato, chilling injury increases rotting and the formation of 'hard-core' a condition where a woody core forms in the storage root. When young cucumber fruits are exposed to chilling temperature, the surface of the fruit is scarred and an undesirable curvature develops. Similarly, when banana fruits are exposed to chilling temperature, there is increase in tannin content, hardening of central placenta, inhibition in starch/sugar conversion and reduction in ascorbic acid content. There is skin pitting, inhibition in conversion of sucrose to reducing sugar in papaya fruits when store in chilling temperature. This type of damage is more acute in other tropical fruits also. Thus, the tropical fruits are to be protected from their chilling in field condition and stored at their appropriate storage temperature.

2.4.3 Frost Damage

Frost occurs through sublimation of water vapour on objects that are below 0^0C. Frost causes damage to the foliage of leafy vegetables as burning symptoms.

2.4.4 High Temperature Stress

Pre-harvest high temperature (during growing) causes losses in post-harvest quality of fruits and vegetables. The losses due to temperature variation vary with species, cultivars, stage of development etc. Direct effects of high temperature stress include damage to cellular membrane, proteins and nucleic acids. Indirect effects include inhibition of pigment formation and degradation. In addition, high temperature causes premature ripening in pumpkin. The oranges grown in the tropics tend to have higher sugar and total solids content than those grown in sub-tropics. However, the tropical grown oranges tend to develop less colour as compared to sub-tropics grown oranges.

2.4.5 Hail Damage

Hail storm size, and its exposure to crop growth stage and duration time are critical factors affecting the degree of damage. Hail damage results in a direct effect on the physical quality of the product, increases the incidence of damage and diseases like bacterial spot (*Xanthomonas campestris* pv. vesicatoria) of sweet pepper.

2.4.6 Soil Condition

The effect of soil on the vegetable produce is largely through its textural properties, drainage, soil reaction and nutrient availability. Soil texture is especially, important for root and tuber crops e.g. hard and compact soil resulted in root forking and stunted growth of carrot and radish.

2.4.7 Pollutants

The toxic elements such as Ag, Cd, Co, Mg, Mn, NI and Zn cause serious damage to vegetables. Air-polllutants such as ozone causes surface blistering of spinach *(Spinacea oleracea* L) leaves, nitrogen dioxide results in marginal and interveinal collapse of lettuce leaves.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Match the following:

Common name	**Scientific name**
a) Cabbage looper	*i) Sternochetus mangiferae*
b) Sweet potato weevil	*ii) Bactrocera dorsalis*
c) Mango stone weevil	*iii) Cylas formicarius*
d) Mango fruit fly	*iv) Trichoplusia nii*

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2. Write the role of environmental factors on post-harvest losses of fruits and vegetables?

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2.5 IMPROPER HANDLING, PACKING, STORAGE AND TRANSPORTATION

2.5.1 During Post-harvest Handling

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept under the shade in the field. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well.

Improper container for packaging capsicum

Owing to their tender texture and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury. Poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, cutting, breaking, impact wounding and other forms of injury. Post-harvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and bruised potatoes may lose three to four times as much weight as non-bruised potatoes.

2.5.2 During Storage

Storage is one of the most important aspects of the post harvest handling of fruits and vegetables. A substantial quantity of fruits and vegetables go waste in our country due to lack of proper storage. The primary purpose of storage is to control the rate of transpiration, respiration, ripening and also any undesirable bio-chemical changes or disease infection. Improper storage resulted in deterioration in fruits and vegetables in following ways:

- Aging due to ripening, softening, and textural and colour changes
- Undesirable metabolic changes and respiratory heat production
- Moisture loss and the wilting
- Spoilage due to invasion by bacteria, fungi, and yeasts and insect pests
- Undesirable growth, such as sprouting of potato

Need and Importance

The field heat of a freshly harvested crop should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to pre cool fresh commodities but only maintain the temperature of pre-cooled produce. Likewise, most refrigerated storage rooms have neither the refrigeration capacity nor the forced air movement needed for rapid cooling. Rapid pre-cooling to the product's lowest safe temperature is most critical for crops with both inherently high and low respiration rates commodities.

Crops with high respiration rate	Crops with low respiration rate
Artichokes, Brussels sprouts, green onions, snap beans, asparagus, broccoli, mushrooms, peas, sweet corn etc.	Nuts, apples, grapes, garlic, onions, potatoes (mature), sweet potato etc.

Pre-cooling methods and appropriate storage temperature and relative humidity for fruits and vegetables are important operations just after harvesting of the produce in order to reduce the post harvest losses.

2.5.3 Storage Temperature

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage. Crops such as cucumbers, eggplant, pumpkin, summer squash, okra, and sweet potato are highly sensitive to chilling injury. Similarly, the tropical and sub-tropical fruits like mango, banana, papaya, pineapple etc. are also sensitive to chilling temperature. Moderately sensitive crops are snap bean, muskmelon, sweet pepper, winter squash, tomato, and watermelon. These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomato, squash, sweet pepper that have been over-chilled may be particularly susceptible to decay such as *Alternaria* rot.

2.5.4 Relative Humidity

Relative humidity is also important in the storage of fruits and vegetables. The relative humidity of the storage unit directly influences water loss in produce. Water loss can severely degrade quality-for instance, wilted greens may require excessive trimming, and grapes may drop loose from clusters if their stems dry out. Water loss also leads to saleable weight loss and reduced profit. Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged at higher temperature level.

2.5.5 Storage Sanitation

Sanitation is of great concern to produce handlers, not only to protect produce against post-harvest diseases, but also to protect consumers from food borne illnesses. *E. coli*, *Salmonella*, Hepatitis, and *Cyclospera* are among the disease-causing organisms.

2.5.6 Ethylene Evolution

Ethylene, a natural hormone produced by some fruits as they ripen. It promotes additional ripening of produce when exposed to it. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to age too quickly. As the fruits age or ripen, they become more susceptible to diseases. Ethylene "producers" should not be stored with fruits, vegetables that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury.

Bad effects of ethylene during storage include:

- russet spotting of lettuce along the midrib of the leaves;
- loss of green colour in snap bean;
- increased toughness in turnips and asparagus spear;
- bitterness in carrots and parsnip;
- yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower;
- accelerated softening of cucumbers, acorn and summer squash;
- softening and development of off-flavour in watermelon;
- browning and discoloration in eggplant pulp and seed;
- discoloration and off-flavour in sweet potato;
- sprouting of potato; and
- increased ripening and softening of mature green tomato.

Ethylene producers include apple, apricot, avocado, ripening banana, honeydew melons, ripe kiwifruit, nectarines, papayas, peaches, pears, persimmons, plantains, and tomato. By and large, more matured and ripened commodities produce more amount of ethylene production.

In regard to reduce cross-transfer of odours, combinations that should be avoided in storage rooms include:

- apples or pears with celery, cabbage, carrot, potato, or onion
- celery with onion or carrot
- citrus with any of the strongly scented vegetables

Pear and apple acquire an unpleasant, earthy taste and odour when stored with potato. It is recommended that onion, nuts, citrus, and potato each be stored separately.

2.5.7 During Transportation

Inland transportation of horticultural crops is usually by rail or by truck. Overseas transportation is by sea or air. A limited amount of high-valued produce is sometimes transported overland by air. The basic requirements for conditions during transportation are proper control of temperature and humidity and adequate ventilation. In addition, the produce should be immobilized by proper cushioning in packs, packaging and stacking, to avoid excessive movement or vibration. Vibration and impact during transportation may cause severe bruising or other types of mechanical injury.

Transportation through trucks

Plastic crates suitable for packaging tomato

Refrigerated containers and trailers are more often used for long distance shipping, whether by sea, rail or truck. Shipping by refrigerated trucks is not only convenient, but also effective in preserving the quality of product. However, both the initial investment and the operating costs are very high. Another possibility is insulated or properly ventilated trailer trucks. Pre-cooled products can be transported through well-insulated non-refrigerated trucks for many hours without any significant rise in product temperature. There are considerable cost savings without any sacrifice of quality if trucks are only insulated, rather than refrigerated, for short-distance shipping. If the product is not pre-cooled or if the shipping distance is long, a ventilated truck is a better choice than an insulated truck without ventilation and without refrigeration. Ventilation alone does not usually provide a uniform cool temperature, but it may help dissipate excessive field heat and respiration heat, and thus avoid high temperature injury.

2.6 SOCIO-ECONOMIC FACTORS

2.6.1 Marketing Systems

Growers can produce large quantities of good-quality fruits and vegetables, but if they do not have a dependable, fast, and equitable means of getting such commodities to the consumer, losses will be extensive. This is further accentuated by lack of communication between producers and receivers, and lack of market information.

Marketing cooperatives should be encouraged among producers of major commodities in important production areas. Advantages of marketing cooperatively include providing central accumulation points for the harvested commodity, purchasing harvesting and packing supplies and materials in quantity, providing for proper preparation for market and storage when needed, facilitating transportation to the markets, and acting as a common selling unit for the members, coordinating the marketing program, and distributing profits equitably.

Alternative distribution systems, such as direct selling to the consumer (roadside stands, produce markets in cities, local farmers' markets in the countryside, etc.) should be encouraged. The Farmer's Market system is to be developed for selling their own fruits and vegetables directly to the consumers. Production should be encouraged as close to the major population centres as possible to minimize transportation costs.

Overcrowded market

Wholesale markets in India are in desperate need of improvement in terms of facilities and sanitation. They are overcrowded, unsanitary, and lack adequate facilities for loading, unloading, ripening, consumer packaging, and temporary storage.

2.6.2 Roads

In India, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply during the season. This is true whether for local marketing or export to other countries. Efficient transport system can go a long way not only in reducing post harvest losses of fruits and vegetables but also in stabilizing the price fluctuation of the same commodity available in different parts of the country.

2.6.3 Government Regulations and Legislation

The degree of governmental controls, especially on wholesale and retail prices of fresh fruits and vegetables, varies from one state to another. In many cases, price controls are counterproductive. Although intended for consumer protection, such regulations encourage fraud and provide no incentive for producing high-quality produce or for post harvest quality maintenance due to non-implementation. On the other hand, regulations covering proper handling procedures and public health aspects during marketing are, if enforced properly, very important to the consumer.

2.6.4 Use of Specific Tools and Equipment

Even if growers and handlers of fresh fruits and vegetables were convinced of the merits of using some special tools and/or equipment in harvesting and post harvest handling, they most likely will not be able to find them in the domestic market. This is true of harvesting aids; containers; equipment for cleaning, waxing, and packing; and cooling facilities. Most of these tools are neither manufactured locally nor imported in sufficient quantity to meet demand. Various government regulations not permit direct import by producers of their needs. It is imperative that the tools that will enable handlers to use recommended technology for a given situation be available for them to use. In many cases, such tools can be manufactured locally at much lower costs than those imported.

2.6.5 Awareness among Common People

The human element in post harvest handling of horticultural commodities is extremely important. Most handlers involved directly in harvesting, packaging, transporting, and marketing in developing countries, have limited or no appreciation for the need for, or how to maintain quality. An effective and far-reaching educational (extension) program on these aspects is needed critically and will continue to be essential in the future.

2.6.6 Maintenance of Equipment

In developing countries like India, some good facilities those were built a few years ago are currently "out of order" or not functioning properly because of lack of maintenance and unavailability of spare parts. This problem is especially true of public-sector facilities. Any new project should include in its plan adequate funds for maintenance to ensure its success and extended usefulness.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write in brief how improper storage resulted in deterioration of fruits and vegetables?

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2. What are the bad effects of ethylene during storage?

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3. Describe in brief, the socio-economic factors responsible for post-harvest losses of fruits and vegetables?

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4. Write short notes on following points in 5 sentences:

   i) Judging maturity index of musk melon and banana.
   ii) Post-harvest Physiology of fruits and vegetables.
   iii) Role of insects in post harvest losses of fruits and vegetables with examples.

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2.7 LET US SUM UP

In this unit, we studied association of both pre and post harvest factors with post harvest losses of fruits and vegetables.

Fruits and vegetables are living entities. The quality and marketable life of these commodities depends on both pre and post-harvest factors. The factors which influence the quality include harvest maturity, choice of cultivars/varieties, climate and soil in which it is grown, pre-harvest infection or infestation of micro-organisms and insects, storage conditions etc. The level of damage suffered by the crop during harvesting and handling can also affect the marketable life. Hence in order to maintain a level of freshness of fruits and vegetables from the field to the dinner table presents many challenges. A grower, who can meet these challenges, will be able to expand his or her marketing opportunities and be better able to compete in the marketplace. The causes of losses occur at different times during the production and post harvest cycle of the crop should be clearly understood before taking control measure. If it is clear that loss is due to infection of micro-organisms the control measures will depend on the type of micro-organisms, the time of infection, the reason for the success of the infection and legislation governing possible control measures.

2.8 KEY WORDS

Physiological maturity : It refers to the stage in the development of the fruits and vegetables when maximum growth and maturation have occurred.

Harvest maturity : It refers to the stage of development when plant or plant parts posses the pre-requisites for utilisation by consumers for a purpose.

Pre-cooling : It refers to the process of quick removal of heat just after harvesting of fruits and vegetables by forced air cooling method.

Climacteric fruits : Fruits where there is upsurge in their respiration after the harvest.

Non-climacteric fruits : Fruits where there is no upsurge in their respiration rate after the harvest.

2.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) v b) iii c) iv d) i e) ii

2. Your answer should include the following points:

   - Role of irrigation
   - Role of mineral or nutrient deficiency
   - Other factors such as weed, crop hygiene, plant protection and use of growth regulators etc.

3. Your answer should include the following points:

   The basic criteria are as follows:

   - Choose cultivars that will have better quality attributes and as per the demand of the consumers.
   - Use clean, healthy, high quality planting materials.
   - Grow off-season cultivars of the same crop to extend harvest period.
   - Choose cultivars that are well suited to the specific climate, day length, soil and growing conditions.
   - Always select seed from the good quality produce or source.

4. Your answer should include the following points:

   Definition of climacteric and non-climacteric fruits and write few examples as given in sub-section 2.1.2.2.4.

Check Your Progress Exercise 2

1. A) iv B) iii C) i D) ii

2. Your answer should include the following points:

   i) Climate
   ii) Chilling Injury
   iii) Frost Damage
   iv) High Temperature Stress
   v) Hail Damage
   vi) Soil Condition
   vii) Pollutants

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Storage Temperature
   - Relative Humidity
   - Storage sanitation
   - Ethylene

2. Your answer should include the role of ethylene in fruit deterioration (bad effects) and measures to take as mentioned in Sub-Section 2.1.2.5.2.4

3. Your answer should include the following points:

   - Marketing System
   - Road
   - Government Regulation and Legislation
   - Use of Specific tools and Equipments
   - Awareness among Common People
   - Maintenance of Equipment

4. Your answer should include the following points:

   i) Mention the proper stage of harvesting of both the crops
   ii) Mention the rate of respiration, ethylene evolution etc. during storage
   iii) Write all about insect damage with suitable example as given in Sub-Section 2.1.2.3.2

2.10 SOME USEFUL BOOKS

1. Bose, T.K. and Mitra, S.K. (1st Ed.) (1985) Fruits: Tropical & Sub-tropical, Naya Prokash, Kolkata

2. Bose, T.K., Som, M.G. and Kabir, J. (1st Ed.) (1985) Vegetable Crops, Naya Prokash, Kolkata.

3. Thompson, A.K. (1st Ed.) (1996) Post harvest Technology on fruits and vegetables, Black Well Science Ltd., UK.

UNIT 3 MATURITY INDICES AND HARVESTING PARAMETERS

Structure

3.0 OBJECTIVES

After studying this unit, you should be able to:

- understand what is maturity;
- distinguish between physiological and commercial maturity;
- determine maturity of important fruits and vegetables; and
- know harvesting time methods, and equipment.

3.1 INTRODUCTION

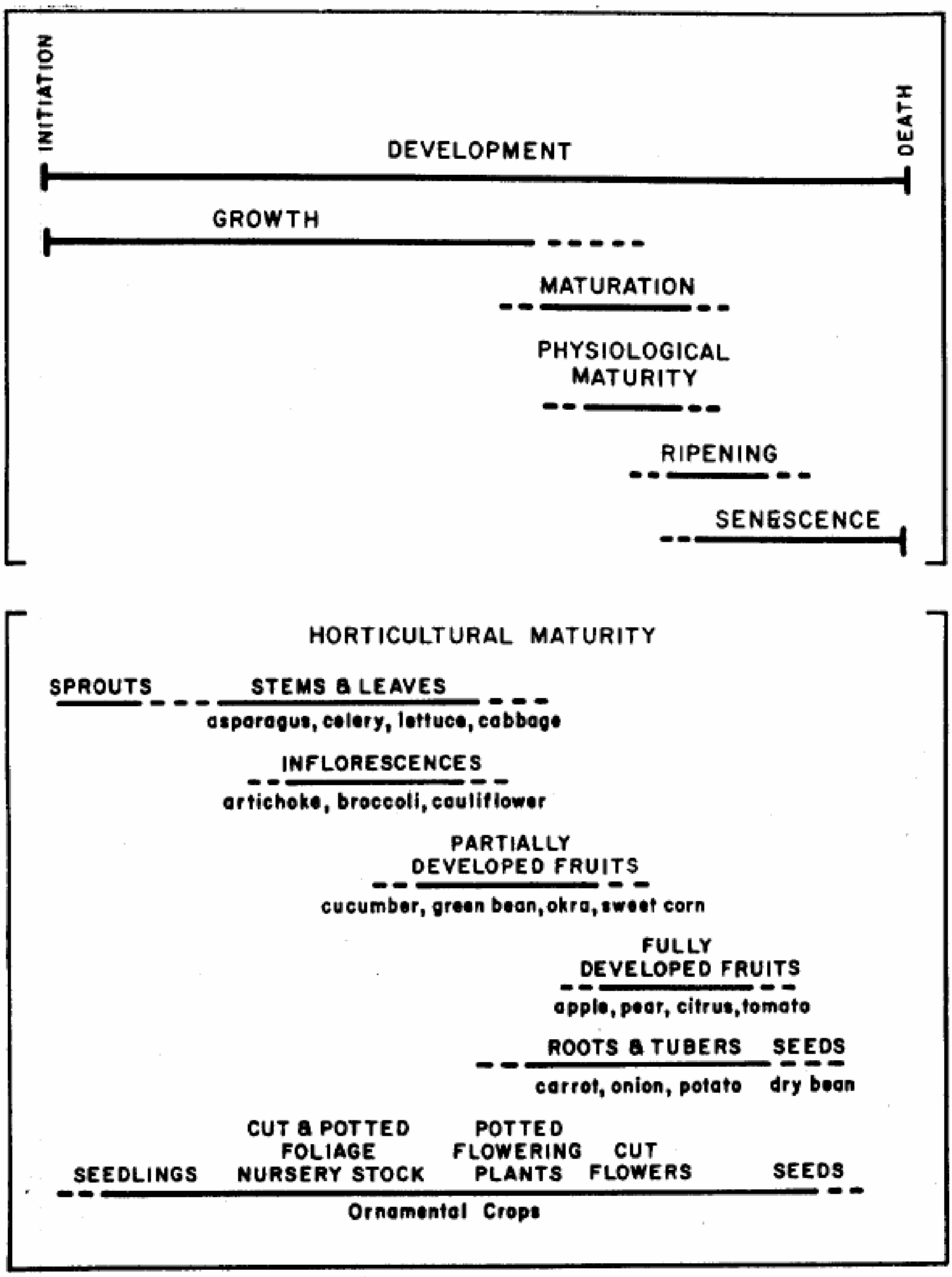
The maturity of fruits and vegetables is an indication of the development of the crop and its progress for becoming a marketable product. Selection of right stage of maturity for harvest is an important aspect, which has considerable influence on storage life and quality and final acceptance by the consumer.

Definition

To most of us 'mature' and 'ripe' means the same thing when describing fruit. But in post-harvest technology mature can be defined as "that stage at which a commodity has reached a sufficient stage of development that after harvesting and post-harvest handling (including ripening, where required), its quality will be at least the minimum acceptable to the ultimate consumer."

Maturity can be of two types – physiological maturity and commercial maturity. Physiological maturity refers to the point in the development of an organ (*e.g.* fruit, leaf) or organism (*e.g.* ornamental plant) when maximum growth has been achieved and the organ or organism has matured to the extent that the next development stage can be completed. In case of fruit, ripening can be considered as the next development stage, preceding the senescence stage.

The commercial or horticultural maturity is the characteristic state of a plant organ required by the consumer. It is concerned with the timing of the harvest to meet particular market requirements. Commercial maturity bears little relation to physiological maturity, and may occur at any stage during development, maturation, ripening or senescence. Examples of commercial maturity include bean sprouts (during early stage of development), cucumber (during maturation) and tomato (during ripening). Chilli can be harvested (commercially mature) at 'green stage' of fruit for 'green chilli' market and at 'red ripe' stage for drying to be used as spice. At both these stages, chilli fruits are commercially or horticulturally mature. The term 'immaturity', 'optimum maturity' and 'over maturity' can be related to these market requirements. To a green chilli market, a red ripe chilli is 'over mature' and to the red ripe chilli market green chilli is 'immature'. Some examples of commercial maturity in relation to physiological age are shown in Figure 3.1



3.2 DETERMINATION OF MATURITY

Determination of the stage of maturity at which a fruit or vegetable should be harvested is important for its subsequent quality, storage and marketable life. Combination of both subjective and objective methods are used to assess maturity of the produce for harvesting. In the former, the appearance; texture, smell, taste comprise the criteria. For the later, the instruments are used to measure colour, ºBrix, sugar, acidity, protein, tannins etc., chemical and physical analyses like determination. These methods can be grouped into physical, chemical, physiological, computation, electronic etc. based on the principles used for measuring the various parameters.

3.2.1 Physical Method

Skin colour

Change of skin colour of many fruits is a valuable guide to maturity. There is gradual loss of intensity of colour from dark green to light green and then development of yellow and/or red pigment (*e.g.* tomato, papaya, litchi, mango). Some fruits like some cultivars of mango, apple, and peach develop red blush colour (i.e. additional colour on the ground colour) as they mature on tree and can be used as maturity index. The assessment of harvest maturity by skin colour changes usually depends on the judgment of the harvester. Colour charts are used for apple, tomato, peach *etc.* Instruments are available for measurement of colour of fruits, and they are mostly used on harvested fruit. On-line commercial colour sorter is used in many crops.

Shape

The shape of fruit and vegetable can change during maturation and this can be used as a criterion to determine harvest maturity For example, some cultivars of banana becomes less angular and more rounded in cross-section. Mango changes shape during maturation on the tree. The shoulder of immature mango fruit slopes away from the fruit stalk and as the maturity advances the shoulder level or becomes raised with the point of attachment with the fruit stalk.

Size

In most crops, size is frequently used to determine when it should be harvested. Sometimes it is related to the market requirement. For example, if a market requires a bottle gourd of 30 cm length, the fruit should not be allowed to grow beyond that limit though the cultivar may be having the potentiality to grow much longer. In banana, the length or width of individual finger can be used to determine harvest maturity. Size also gives rise to volume and is often expressed as weight to determine harvest maturity of many fruits and vegetables like mango, watermelon, pumpkin. When we divide weight by volume it gives density (g/cm^2) and is used as maturity index in potato. The size is also used for grading of many fruits and vegetables and machines have been developed for size grading.

Firmness

As fruits mature and ripen, they soften because of dissolving of pectin comprising the middle lamella of cell wall. This softening can be estimated subjectively by the finger feel of commodity. It can objectively be measured using a fruit hand held pressure tester (also called penetrometer). These testers measure the pressure at which flesh yields to the penetration of a standard diameter plunger inserted to a standard depth. More sophisticated tests can be carried out using machines such as Instron Universal Testing Machine. But these machines are mainly used for experimental studies.

Specific gravity

Specific gravity is the relative gravity or weight of solids or liquids compared to distilled water at 62°F (16.7°C). To determine specific gravity the fruit or vegetable is weighed in air and in distilled water and its weight in air is divided by the loss of weight in water. As fruits mature their specific gravity increases. This parameter is rarely used in practice to determine when to harvest, but can be used as a sampling technique. It is used, however, to grade the produce into different maturity groups after harvesting. To do this, fruits or vegetables are placed in a tank of water, those that float are less mature than those that sink. To increase effectiveness sometimes salt is added to the water at 1% to 2% concentration.

Aroma

Most fruits synthesise volatile chemicals as they ripen. These give the fruit its characteristic flavour and can be used to determine whether fruit is ripe or not.

3.2.2 Chemical Method

Sugars

As the fruit ripens, starch is broken down to sugars. Measurement of sugars can provide an indication of the stage of maturity or ripeness. In practice, the soluble solids, also called degree brix, are measured in the fruit juice. Usually the sugars constitute the major portion of soluble solid of the fruit juice. So measurement of total soluble solid (TSS) can give a reliable estimate of sugar in fruit juice. This is done using a refractometer or a brix hydrometer, which provide quick and easy methods for assessment of ripeness. This can be used in grape, muskmelon, mango etc.

Starch

Measurement of starch content in the developing fruit of pear and apple provides a reliable method for assessing their harvest maturity.

Acidity

The acidity of many types of fruit changes during maturation and ripening. In citrus, mango, pineapple and many other fruits acidity progressively decrease as the fruit matures on the tree. Taking samples of these fruits, extracting the juice and titrating it against a standard alkaline solution give a measure of acidity, which can be related to determine harvest maturity. Normally, acidity is not used singly; it is related to soluble solids, giving what is called sugar acid ratio.

3.2.3 Physiological Method

Climacteric fruits, in which there is a distinct rise in respiration during ripening, can be sampled, kept at a relatively high temperature and respiration rate measured. By doing this, it may be possible to predict the number of days the fruit would have taken to commence the climacteric rise if left on the tree.

3.2.4 Computation Method

The time required between flowering and fruit being ready for harvesting may be measured by 'heat units' or 'degree days' in a particular environment. It has been found that a characteristic number of heat units or degree days is required to mature a crop. Maturity will be advanced under warm conditions or delayed under cooler conditions. The number of degree days to maturity of a particular crop or a variety is determined over a period of several years by obtaining the sum of the difference between the daily mean temperature and a fixed base temperature (commonly the minimum temperature at which growth occurs). For example:

20-15°C (minimum base temp.) × 1 day = 5
25 -15°C = 10 × 2 days = 20; total 25 degree days

Likewise the computation is continued and when the total number of degree days reaches say 1000 for a particular crop it is presumed that the crop is ready for harvest. As maturity approaches the correct stage of the crop may be checked by other means. This method is helpful in planning planting, harvesting and factory management programme for annual processing crops such as pea, tomato *etc*.

3.2.5 Electronic and Other Methods

Electronic principles are used in various machine used in determining the maturity.

Electronic colour sorter

This machine is used in packing houses to sort out fruits on the basis of colour *e.g*. in apple, orange *etc*.

Acoustic and vibration test

The sound of a fruit when tapped with the knuckle of the finger, changes during maturation and ripening. Consumers often use this method for testing when purchasing watermelon. Farmers also use this for determining maturity. Sophisticated machines have been developed to measure the sound of tapping for precise determination of maturity.

Electromagnetic method

Nuclear magnetic resonance (NMR) spectroscopy is used in human pathology to provide images of the inside of the body. Such instrument has been found to be useful in determining maturity by examining internal structure of fruit.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is maturity and how will you differentiate between physiological and commercial maturity?

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2. What are different methods for determining harvest maturity? Describe simple and easy to use methods.

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3.3 MATURITY INDICES OF COMMERCIALLY IMPORTANT FRUITS

Mango

The various criteria recommended for judging maturity are red blush colour development on the shoulders, falling off of one or two ripe fruits from the plant naturally, the specific gravity of fruit ranging from 1.01 to 1.02 and in general fruits attain maturity 90-120 days from the fruit set stage. Sometimes maturity indices like change in pulp colour from white to pale yellow and slowing down of latex flow from the stalk of plucked fruits also serve the purpose.

Banana

The fruits are usually harvested when the ridges on the surface of the skin change from angular to round *i.e.* after the attainment of the ¾ full stage. The maturity of fruits can also be adjudged by some other physical characters and chemical analysis. The physical characters like change in skin colour or development of blush or visually lighter colour is also taken into account to determine the maturity of fruits. In addition, fruits attain the size specific to variety on maturity. However, for long distance transport attainment of ¾ maturity is taken as harvesting index.

Citrus

The fruits are generally harvested when the changes in rind colour take place. The colour break stage (change in colour from green to yellow) is taken as criterion for judging the maturity of lime and lemon. In citrus, total soluble solid (TSS): acid ratio is considered to be a good index for judging maturity, which varies from variety to variety.

Papaya

The fruits should be left on the tree until they mature fully. Usually the fruits are harvested when they are of full size, light green with a tinge of yellow at apical end. On ripening the latex becomes watery from milky.

Pineapple

The fruits are usually harvested when the surface colour is between colour break and quarter yellow for shipment by sea and a half to three-quarter yellow colour for transportation by air. Harvesting for local market and distant market should be done at the full maturity stage and 75-80 per cent maturity stage, respectively. At maturity, the eyelets get flattened.

Grapes

In grapes, the basal berries mature and ripen first and the harvesting of immature berries are never advisable as these do not ripen after harvest. The physical appearance like change in colour from dark green to light green, yellow or red or purple depending upon the type of cultivars, glossyness and softness of berries are also taken as indices for judging maturity. The estimation of TSS: acid ratio is also taken as criteria for judging the maturity. The TSS and acidity of berries are determined by refractometer and titration, respectively.

Sapota

In sapota, various criteria have been suggested for judging the maturity *e.g.* development of a dull orange colour or potato colour, showing light yellow streak instead of a green streak when scratched and disappearance of browny scales on the fruit surface.

Guava

Guava fruits mature 4-5 months after flowering. At maturity the specific gravity varies from 0.95-0.96, while TSS and acid content ranges from 12-13° Brix and 0.36 to 0.41% respectively.

Jackfruit

Several indices are commonly used to determine the optimum time to pick the fruits. A dull, hollow sound is produced when the fruit is tapped by the finger; the fruit spines become well developed and wide spaced; the spines yield to moderate pressure and lastly there is development of aroma. For distant market, fruit should be harvested when still firm and without any aroma.

Pomegranate

The fruits are ready for harvest in 5-6 months after flowering. The fruits are picked when the skin turn slightly yellow and the fruit gives a metallic sound when tapped. Likewise, the ripe fruits give a distinct cracking sound of grain cracking when pressed slightly on the slices.

Apple

Apple may be harvested when a fruit separates easily from the branch, retains firmness of pulp and taste which are desirable. On maturity the skin colour changes from green to yellow or red depending upon the cultivars. The days from complete flowering can also be taken as a criterion to assess the maturity, which varies from 90±4 days in early maturing varieties to 180±5 days in late maturing varieties.

Pear

Pear is harvested when firm and green for canning, while fully mature fruits are harvested for fresh consumption. Days from full flowering, TSS and firmness can also be used for judging the maturity.

Peach

Various criteria have been advised for judging the maturity of peaches like fruit size, shape, firmness, starch content of fruits *etc*. Usually peaches are picked when they are still hard as they can ripen well in storage or in transit.

Plum

Change of ground colour of fruits from green to yellow or red depending upon the varieties, firmness and TSS content of fruits and days from full flowering are used to assess the maturity of fruits.

Strawberry

Strawberries are generally harvested when half to three-fourth of skin develops colour. For distant shipment green or white and still hard berries are harvested.

3.4 MATURITY INDICES OF COMMERCIALLY IMPORTANT VEGETABLES

Broccoli

The best stage of harvesting is before the buds begin to open, the heads remain compact and the yellow petals have not come out. The total length of the stalk and the head can be 15 to 25 cm depending on the variety. The axillary shoots grow and form smaller heads sometime after harvest of the main head. These can also be harvested for marketing.

Cauliflower

Stage of maturity is determined by curd size and its compactness. If harvesting is delayed, the curds become loose and discoloured. If the produce is meant for storage, it is better to harvest when the curds are not fully exposed and still covered with central whorl of leaves.

Cabbage

Solidity and firmness of the heads are the usual maturity characteristics used. Colour of the head is used as an added index. The head turns a lighter shade of green when full development is attained.

Celery

Generally, celery requires blanching, although some growers prefer to sell it green. There is no specific time of harvest for celery though some like to harvest it as early as possible to take advantage of higher price. Blanching of the petioles and stalks and slight enlargement of the heart and inner leaves are used as picking indices.

Carrot

Depending on the variety, the attainment of desired size is the primary consideration. Marketing of roots begins as soon as they attain acceptable size even though they have not attained full size specific to the variety. The roots must be harvested before emergence of the seed stalk.

Cucurbitaceous vegetables

In general, cucurbit fruits mature faster. In such kind of vegetables like summer squash, Indian squash (tinda), bitter gourd, small (gherkin) cucumber and long melon, fruits reach optimum maturity stage within a week or so after fruit set. In other kinds of vegetables like sponge and ridge gourds, bottle gourd, snake gourd, pointed gourd *etc*., picking is done in about 12 to 15 or even 20 days after fruit set. In sponge and ridge gourd the flesh should not turn fibrous. In bittergourd, fruits should not turn yellow or yellowish orange in transit, hence, these are to be harvested at green stage. In musk and watermelon, 30 to 40 days will be required for the fruits to reach harvest maturity.

Picking of fruits at the right edible maturity stage is dependent upon individual kinds and varieties. In salad or slicing cucumber, dark green skin colour should not turn into brownish yellow and white spine colour will also be an useful indication of edible maturity. Over-mature fruits will show carpel separation (development of gap in the flesh) in transverse section.

In muskmelon, there are two groups of cultivars which behave distinctly. In one group, the fruits when mature slips out easily from the vine with little pressure or jerk or if not it will remain separated from the vine next day. This is called full slip stage. Most cultivars including Indian varieties and cantaloupes of the USA behave in this way. The cantaloupes can be picked at ¾ slip stage for long distance transport. There is another group of melon like Honey Dew and Casaba, the fruits of which do not separate at maturity and they have to be picked on the basis of external colour. In some Indian cultivars, green stripes on the skin begin to turn yellow which is an indication of full maturity. Muskmelon is a climacteric fruit which ripens during transit and storage and hence it is harvested before it is fully ripe.

In watermelon, maturity is judged by taking into consideration of several factors: (i) dull sound when the fruit is thumped, in contrast to metallic sound, (ii) withering of tendril at the fruit axil, (iii) ground spot turning yellow, (iv) rind of the ripe melon yields to pressure. Cumulatively all these criteria will help judge correct stage of picking.

Eggplant

Fruits should be picked as soon as they have attained the desired size, before they harden or show streaks of unusual colour. The skin should be bright and glossy and seeds undeveloped.

Tomato

Harvesting depend upon the purpose for which it is grown and time to be taken for reaching the destination. Six maturity stages are recognized. These are mature green, breaker, turning, pink, light red and red. In 'breaker' stage only up to 10% of the fruit surface especially at the blossom end is pink or red and in 'red' stage more than 90% of the fruit surface is red. In India fruits, for a distant market, are harvested at 'breaker' stage and they ripen during transit. For nearby market and for processing, it is better to harvest at a latter stage.

The colour of the fruit can be measured by a colour chart or a colour measuring instrument using light transmittance technique.

Potato

Setting of skin, starch content and leaf senescence are harvest indices. To catch early market and to get high price, potatoes are also harvested before attaining full maturity. These tubers are not fit for storage and should be disposed of quickly.

Garlic and onion

Onions are harvested depending upon the purpose for which the crop is grown. It requires 45 to 90 days from field setting for green onions and 90 to 150 days for bulb depending upon the variety. Onions should be harvested one week after 50% crop shows neck fall. Garlic is ready for harvesting when the tops turn yellowish or brownish and show signs of drying up and bend over.

Okra

Fruits are harvested when they are tender and exhibiting maximum growth rate. At this stage, the blossom end of the fruits, when bent, breaks easily. It takes 7 to 8 days to become ready for harvesting after fruit set. Frequent picking promotes fruit development and increases yield.

Pea

Quality of pea depends on sugar content and tenderness. With increasing maturity and size, sugar declines rapidly with an increase in starch and protein. Thus a high sugar content is an indication of high quality. The appearance of the pod is an added indication of maturity. Since firmness increases with maturity, a tenderometer is used to measure tenderness. Calculation of degree days is also done for mechanical harvesting.

Radish

The crop matures in 3 to 4 weeks in case of quick growing varieties and in 8 to 10 weeks in case of the Chinese varieties. The crop is harvested when the roots are still tender before they become pithy and fibrous.

3.5 HARVESTING

The objective of harvesting is to pick the fruits or vegetables at the proper stage of maturity, with a minimum damage, as rapidly as possible and at a minimum cost. This objective is best achieved by hand harvesting in most fruits and vegetables.

3.5.1 Hand Harvesting

Hand harvesting is the most advantageous method. It offers several advantages:

1. Selection of proper stage of maturity is accurate.
2. Humans can handle fruits and vegetables with minimum damage.
3. Multiple harvesting is possible.
4. Requires less capital investment.

Need and Importance

Care in harvesting and handling is necessary to preserve subsequent quality. Bruises and injuries may later show up as black or brown patches, making the commodity unattractive. As far as possible, harvesting should be done during cooler part of the day and the harvested material should immediately be removed to a shady place. Harvesting immediately after rain dew/snow should be avoided as it creates conditions most favourable for multiplication of decay causing pathogens.

a) Fruits

Soft fruits such as strawberry which are borne on low growing plant, are simply removed from the plant and are put into a suitable container. Sometimes they are directly put into the consumer carton for sending to the market. Fruits which are borne on tall or medium tall trees such as mango, citrus, sapota, guava, apple *etc*. are difficult to harvest and the process is time consuming. A long pole with some cutting device and a bag at the end is commonly used. Some improved harvesters have been developed in India by ICAR institutes and SAU'S viz. IARI, New Delhi, IIHR, Bangalore, KKV, Dapoli and CISH, Lucknow. These harvesters have been tested successfully in several crops and have been found to be more efficient and economical than manual harvesting by hand only. It has also been reported that fruits harvested by cutting the fruit stalk rather than twisting and pulling, had lower incidence of rotting during subsequent storage.

b) Vegetables

Most vegetables are hand harvested even in the developed countries. Root crops like potato, onion, garlic, colocasia and tapioca are dug out with the help of fork or spade. Other root crops like radish, turnip, carrot and beet are pulled out of the soil. All damaged roots should be sorted out as early as possible. Fruit vegetables like okra, brinjal *etc*. require some cutting device like krives/siezzer/sickle sickle. Tomato usually does not require such device and pulling by hand can detach the fruits. Muskmelon at full-slip stage does not even require any pulling by hand. At half-slip stages a little jerk may be required in Pumpkin, bottle gourd, bitter gourd, sponge gourd, ridge gourd etc. require some cutting device for harvesting. Cauliflower and cabbage are harvested by cutting the stalk with some sharp tool. Leafy vegetables like amaranth, spinach, spinach beet (Palak), *Trigonella* (Methi) *etc*. may be harvested by picking the leaves or by cutting with sickle depending on the market requirement.

3.5.2 Mechanical Harvesting

Mechanical harvesting has certain advantages:

1. It is a quicker method.
2. Problem associated with labour management is less.

There are certain disadvantages too:

1. It damages perennial crops (e.g. damage to bark by a tree shaker)
2. There may be a lack in processing and handling capacity to handle high rate of harvest.
3. There is less chance of selection of fruits.
4. Damage due to mechanical injury is more.
5. It is more expensive.

a) Fruits

Very little fruit destined for fresh market is harvested by machines because the likely damage could result in rapid deterioration of quality. Fruits for processing may be harvested mechanically. Oranges for juice extraction may be removed from the trees by powerful wind machines being dragged through the orchard followed by collecting oranges from the ground mechanically or manually. Tree shakers are also used. These methods may cause considerable damage to fruits. Grapes can be harvested for wine making using tractor-mounted machines with combing fingers made of rubber which are run up the stems, pulling up the fruit bunches along with leaves. In banana, bunches are cut manually and then conveyed by hanging conveyor rope. Sometimes conveyor belts are also used.

b) Vegetables

Mechanical aids to harvesting vegetables such as cauliflower, cabbage, lettuce involve cutting by hand and placing them on a conveyer of a mobile packing station which is slowly conveyed across the field. Peas for processing are harvested by combine. Tissue damage during harvesting has been reported to develop off flavour due to enzymatic reaction in pea. Mechanical harvesting of French bean may cause breaking of the tips. In potato, mechanical harvester removes the tubers from the soil and by mechanical shaking, soil clods are broken into fine pieces for easy removal of potato from the soil. In developed countries the entire operation of digging and removal of potato is done by machine. In India, in some parts of the country, mainly digging is done by the potato harvester. In some countries, onion is harvested mechanically after cutting the tops mechanically before harvesting. Similar harvester can be used for sweet potato. Harvesters for tapioca and yam have been less successful. Tapioca harvesters for processing are common but the roots must be processed quickly after harvest to avoid deterioration.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Outline maturity indices of important fruits.

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2. Outline maturity indices of important vegetables.

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3. What are the merits and demerits of hand and mechanical harvesting?

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3.6 LET US SUM UP

In this unit, you have read about maturity of fruits and vegetables, methods of determination of harvest maturity, maturity indices of important fruits and vegetables and their harvesting methods. It has given you an idea about the advantages and disadvantages of hand and machine harvesting. It has also highlighted the simple and commercially followed methods for determining maturity stage for harvesting.

3.7 KEY WORDS

Maturity : It is a phenomenon by which a commodity (fruit or vegetable) reaches a sufficient stage of development that after harvesting and post-harvest handling; its quality will be at least the minimum acceptable to the ultimate consumer.

Physiological maturity : It refers to the point in the development of an organ or organism when maximum growth has been achieved and the organ or organism is ready for the next development stage to be completed.

Horticultural or commercial maturity : It is the characteristic state of a plant organ required by the consumer. It is concerned with the timing of the harvest.

Maturity indices : These are the criteria which are used to determine whether a crop has reached a proper stage for harvesting.

3.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Definition of maturity.
   - Classification of maturity into two types – physiological and commercial and differences between them.

2. Your answer should include the following points:

   - Grouping of methods of determination of maturity into physical, chemical, physiological, computation, electronic and others.
   - Description of methods grouped under physical group.

Check Your Progress Exercise 2

1. Maturity indices of important fruits are to be written.
2. Maturity indices of important vegetables are to be written
3. Merits and demerits of hand and machine harvesting are to be discussed.

3.9 SOME USEFUL BOOKS

1. Kader, A.A. (ed.) (1992) Post-harvest Technology of Horticultural Crops (2nd edition), University of California, Berkley.

2. Thompson, A.K. (2003) Fruits and Vegetables: Harvesting Handling and Storage, Blackwell Publishing, UK.

3. Watada, A.E., Herner, R.C., Kader, A., Romani, R.J. and Staby, G.L. (1984) Terminology for the description of Developmental stages of horticultural Corpp. Hort. Science, 19: 20-21.

4. Wills, R., McGlasson, B., Graham, D. and Joyce, D. (2004) Post-harvest (4th edition), CAB International, U.K.

UNIT 4 PACKAGING OF FRUITS AND VEGETABLES

The main objective of packaging is to keep the fruits, vegetables and root crops in good condition until it is sold and consumed. Good packaging gives more choice to consumers in terms of food availability and encourages the customers to purchase the product. Packaging also enhances the income of rural producers from surplus produce.

Structure

4.0 OBJECTIVES

After studying this unit, you should be able to:

- know the types of post harvest losses;
- select good packaging material for fruits, vegetables and root crops;
- describe different types of packaging material;
- know the types of cushioning material; and
- explain how post-harvest handling and marketing can be improved through better packaging.

4.1 INTRODUCTION

Do you know that India now occupies first place in the world in the production of fruits and vegetables. But increased production of fruits and vegetables will have significance only when they reach the consumer in fresh and palatable condition at a reasonable price. Due to heavy post harvest losses, there is a considerable gap between production and availability of fruits and vegetables to consumers. Post-harvest losses are occurring in the period between harvesting and consumption. The term losses include all types of losses for the farmers, traders and consumers (e.g. weight loss, quality loss, financial loss,

loss of goodwill, loss of marketing opportunities, loss of nutritional value, etc.). Hence there is an urgent need to adopt proper post harvest management practices by adopting improved packaging, handling and efficient transportation methods.

Packaging is

- Assembling the produce in convenient units for transport, distribution, storage, retailing and end use.
- Ensuring safe delivery to the consumer in sound condition at minimum cost.
- It must prevent losses, increase marketability and decrease the handling and transportation cost.

Packaging of fresh fruits, vegetables and root crops is one of the most important steps in the long and complicated journey from grower/farmer to consumer. Packaging extends the shelf-life to local surpluses of food and thus allows the food to be distributed to other areas.

Good packaging has two purposes, which are functional and aesthetic. Functional purpose aim at extending the shelf life to the product by protecting the produce from the hazards of transportation, microbial, insect/ pest damage and physiological and biochemical changes. Aesthetic aspect of packaging aims at attracting the consumer in terms of shape, size, colour and convenience etc of the packaging and identifies the product in the market, which enhances brand loyalty.

Most predominately used packaging materials for fruits, vegetables and root crops are wood followed by jute, bamboo, and corrugated fibre boards. More recently the use of plastics are becoming more convenient due to maximum reusability.

There are mainly two categories of packaging: (i) Retail packaging and (ii) Bulk shipment packaging.

Retail packaging: The materials used for retail or small unit packaging are different in different ecological locations, subject to availability around the producing centres. For example Polyethylene films (HDPE, LDPE), boxes, bags, tray type containers etc.

Bulk Shipment packaging: Corrugated boxes, molded pulp trays, foamed polystyrene trays are used for bulk shipment.

The type of package used depends upon the shape and the perishability of the product. Based on this, there are five main classifications:

Produce	Common Package Recommended
Soft fruits	Semi-rigid containers
Hard fruits	Open tray
Stem products	Bags or wrappers
Root vegetables	Polyethylene bags
Green vegetables	Polyethylene or Polystyrene bags

4.2 SELECTION OF PACKAGING MATERIAL

How to select packaging material for a particular commodity? What are the points we should consider to select the packaging material?

Package is selected in accordance with the product characteristics. Now what is the product characteristics based on which the package is selected? They are physical and physico-chemical.

Packaging material is selected on the basis of:

- The commodity itself.
- The systems of production, storage, handling, transportation.
- Cost factor involved in producing packaging material
- Market requirement
- Consumer attitude.
- Requirement of recycling, re-use disposal etc.

The important considerations in selecting packaging material for fruits, vegetables and root crops are:

1. Easy to open and close
2. Easy to fill
3. Easy disposal
4. Easy to recycle
5. Pilfer-proof
6. Eye appeal
7. Should withstand rough handling
8. It must provide adequate ventilation to contents for rapid cooling during transport and storage.
9. It must be readily available.
10. The package should be large enough to hold melons and pumpkins, but should also be suitable to hold smaller produce.
11. It must be cost-effective in terms of the market value of the commodity for which used;
12. Its dimensions and design must be suited to the available transport in order to load neatly, firmly with full capacity.
13. It should be easily transported when empty and occupy less space than when full.

Packages should be of a size, which can be easily handled. The ratio of weight of the container to that of the produce it contains is important. Where transport charges are calculated on a weight basis, heavy packaging can contribute significantly to the final cost of the saleable product. The shape of packages is also significant because of the loading factor, the way the load is positioned on the transport vehicle for maximum capacity and stability. Round baskets hold considerably less produce. A cylindrical basket contains only 78.5 percent by volume compared with a rectangular box occupying the same space.

Suitable packaging for any product requires good ventilation to prevent the build up of heat and carbon dioxide (Heat and carbon dioxide decreases the keeping quality of the produce and leads to development of off-flavour of the produce). The ventilation of produce is very important with adequate air flow through stacked packages. The effectiveness of ventilation during transport also depends upon the air passing through the load. Sacks and net bags must be stacked so that air can circulate through the contents.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the post-harvest loses? How to prevent them?

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2. What are the main criteria for selection of packaging materials?

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4.3 FUNCTIONS AND PROPERTIES OF PACKAGING MATERIAL

What are the primary functions of packaging? Why do we pack a particular commodity in a specific package?

Two main functions of packaging are:

1. To assemble the produce into convenient units for handling.
2. To protect the produce during distribution, storage and marketing.

Packaging materials used serve the following purposes.

1. Serves as an efficient handling unit
2. Protects from mechanical damage
3. Protects against moisture loss
4. Provides clean and sanitary storage
5. To prevent pilferage
6. Provides sales and service motivation
7. Reduces cost of transport and marketing

Need and Importance

The basic functions of packaging are:

a) Containment – protects the loss of produce by holding together a definite quantity as per market requirement.

b) Protection against climate, water vapour, oxygen, light, transport shock, vibration, decay etc.

c) Preserving quality (microbial, freshness & aesthetics attributes)

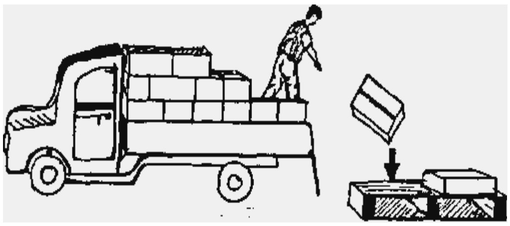
d) Information about the products, producer, content and legal requirements.

Packaging serves as an efficient handling unit to carry produce from field to consumer. It must allow removal of metabolic heat during storage and transport, and may have to contain the perishable produce throughout its ripening process. Proper ventilation is essential for this. Some commodities (e.g. avocados) that are highly sensitive to ethylene (ripening gas) require packages that permit effective ventilation so as to avoid excessive gas build up in transit.

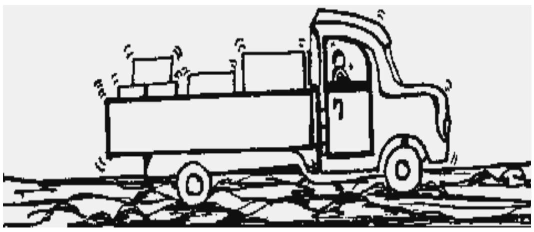
The package should also protect the produce against rotting. Perforated polyethylene liners that allow gas exchange are used for some produce. The special treatments given to certain produces (e.g. sulphur dioxide treatment of grapes and in-package use of ethylene absorbents) must be taken into consideration in package design.

Packages must protect against possible damage. Various kinds of impact and other shocks must be taken into consideration in the design of the package and its fittings to minimize this risk. Impact damage (bruising) result from dropping the individual products or letting the package fall onto a hard surface. Such damage may be avoided by careful handling, use of inserts and improvements in cushioning materials. Damage caused by compressions results from overfilling, and from incorrect and unsuitable packaging.

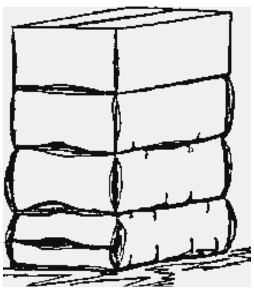
Transportation hazards



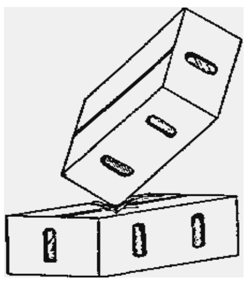
Package falling onto a hard surface



Damage caused by improper filling



Compressions results from overfilling



Damage by puncturing

(Source: FAO)

4.4 PACKAGING MATERIALS FOR FRUITS, VEGETABLES AND ROOT CROPS

There are many different types of package in use throughout the world. Packaging for fresh produce is of several types:

4.4.1 Basket made of woven strips of leaves, bamboo, plastic etc.
4.4.2 Sacks: flexible, made of plastic or jute.
  i) Bags: small size sack
  ii) Nets: sacks made of open mesh
4.4.3 Wooden crates
4.4.4 Fiberboard boxes
  i) Solid fiberboard boxes
  ii) Corrugated fiberboard boxes
4.4.5 Plastic crates
4.4.6 Biodegradable plastics
4.4.7 New innovations in packaging of fruits, vegetables and root crops
4.4.8 Pallet boxes and shipping containers.

4.4.1 Baskets

Baskets are made from woven strips of leaves, plastic and bamboo. Bamboo baskets of different shapes and sizes are used for number of perishable commodities. As the dimensional stability and ability to withstand stacking load is low, they are suitable for head load only and for very short distance transportation only. These packages are not strong enough to withstand rough handling and they are not rigid enough to take the stacking load of more than two or three baskets.

4.4.2 Sacks and Nets

The materials used for sacks and nets may be woven natural fibre (jute, cotton), woven synthetic (polypropylene, polyethylene), knitted natural fabric (cotton), knitted synthetic (polyethylene) or non-woven synthetic (propylene).

Plate 1: Jute bags

Advantages and disadvantages of sacks and nets

The advantages of using sacks and nets are merely financial. The sacks and nets are cheap, have a low weight/volume ratio and, if made of a synthetic material, will not rot. The disadvantages include a low protection against puncturing, compression, vibration and impact injuries such as dropping, difficult stacking, and the need of special stitching equipment. In general, nets are only suitable for hard produce such as coconuts and root crops (potatoes, onions).

4.4.3 Wooden Crates

Commonly used are wire bound crates for citrus/potatoes, wooden trays for tomatoes and wooden field crates.

The advantages of wooden crates are:

1. The crates can be manufactured and repaired locally.
2. Wood is relatively resistant to different weather conditions and water.
3. Wooden crates are often reused and have a higher efficiency for larger fruits, e.g. watermelons.
4. Most crates have good ventilation.

Disadvantages of wooden crates are:

1. Untreated wood can easily become contaminated with fungi and bacteria.
2. Treatment of wooden crates with paint or other chemicals may cause produce deterioration.
3. The material may be too hard or rough for produce like soft fruits, and therefore liners of a soft material may be needed.
4. Manufacturing of wooden crates puts an extra claim on the natural forest resources.

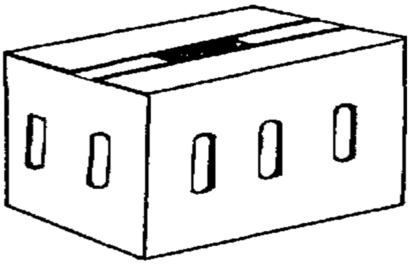
A wooden crate consists of rigid corners with planks nailed or stitched against those corners (e.g. apple or pear crate, field crate).

Plate 2: Wooden crate

4.4.4 Solid and Corrugated Fibreboard Boxes

Fibreboards are of two types viz. CFB (Corrugated Fibre Board) and SFB (Solid Fibre Board). Fibreboard boxes are frequently used because of their low weight, their range of sizes and shapes and their availability.

Solid fibreboard boxes (cartons): The boxes are used for tomato, cucumber and ginger transport. Most of them are printed with attractive colours, a brand name and a label. The information can be stamped on this label after filling the box.



Advantages of solid fibreboard boxes

- Low weight and easy to handle.
- The box can have any design, although it is recommended to use sizes fitting on the standard design of pallets.
- The boxes are delivered flat and assembling boxes can be done locally.
- The box has a low purchase cost.

Disadvantages of solid fibreboard boxes

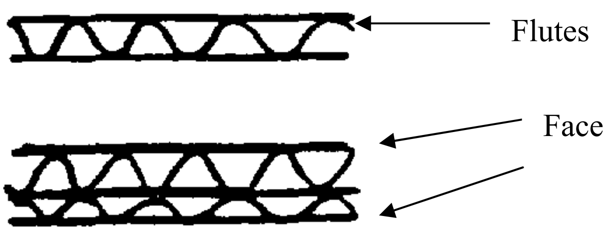
- Moisture and high humidity can seriously weaken the box. Washed produce should be made free from surface moisture before putting it into the box. Empty boxes should be stored in a dry place preferably flat on top of pallets and not for long periods of time.

- The low rigidity causes the lower stacking strength compared to wooden or plastic crates. The fibre-board boxes are easily damaged by rough handling and ropes and too much weight on top of the box can crush the perishable produce inside.

- Ventilation holes are usually small, because large holes would seriously influence the strength of the box. It is advised that the hole surfaces area is kept at least 5 percent of the total surface area of the box. Decreasing the size of the holes by not properly closing telescope boxes or not properly stacking the boxes will decrease heat exchange, resulting in higher temperatures of the produce and increased spoilage. Vertical oblong slots, instead of round holes, have the advantage that the hole stays partly open even when the telescope box lid is not completely closed.

- The boxes are not re-usable.

Corrugated Fiberboard (CFB): Corrugated fiberboard is manufactured in many different styles and weights. Because of its relativity low cost and versatility, it is the popular produce container material and will probably remain so in the near future. The flat surfaces of CFB boxes are known as 'face' and the corrugated surfaces are known as 'flutes'. The strength of CFB primarily depends on the GSM (g/m^2) of kraft paper used, no. of flutes/ meter and the height of the flutes.



The advantages of corrugated fiberboard boxes are:

Low weight, easy to handle, *cushioning* effect due to relatively soft walls. The CFB box can be fabricated to any design, the boxes are delivered flat and assembling of boxes can be done locally. They also have good printability. Above all they are most eco-friendly package due to their *biodegradability*.

Plate 3: Corrugated fibreboard boxes

However, low rigidity and poor stacking strength, high moisture absorbance, and low re-usability are the major disadvantages of CFB boxes. While packaging of fresh horticultural commodities, attention must be given for proper gaseous exchanges by providing required ventilation holes. As a rule, ventilation area should be at least 5 per cent of the total outer surface area of the box. Vertical/ oblong slots are better than round holes. Sometimes coatings with wax or poly linings are also used in CFB boxes in order to make them moisture proof.

4.4.5 Plastic Crates

In general, plastic crates are more expensive than wooden crates or carton boxes, initially but in long run they work out to be cheaper because of their more usability and longer life span. Plastic crates are usually made of high-density polyethylene (HDPE) or polypropylene (PP).

Advantages of plastic crates:

- As a strong, rigid crate, these plastic crates can be used for many journeys, making the cost per journey relatively low.
- Different sizes and shapes are available to suit different customer needs. Colours can be used for marketing purposes.
- The containers are easy to clean and disinfect.

Plastic crates are strong and water resistant and therefore, the containers can be used in humid areas and during hydro cooling.

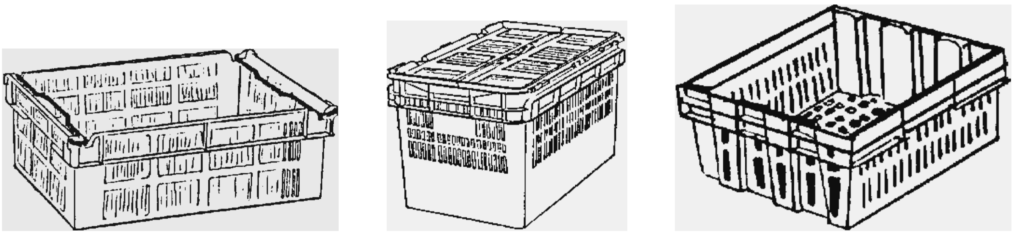
Disadvantages of plastic crates:

- The hard surfaces can damage the produce and it is advised to use liners at the bottom and side.
- The high purchase cost combined with the risk of pilferage could make this type of crate a financial risk.
- Because this crate can be used several times, the extra cost for the return trip should be included in the total running cost.

- The loss of space (40-80 mm on the sides and around 10 mm from the height).

a) *Stacking crates*

Because of the squared design with only the corner slightly rounded, an efficient use of available space is possible.



Plastic Crates (Source: FAO)

4.4.6 Bio-degradable Plastics

Plastic recycling is usually not as straightforward as for the other packaging materials. Many companies/institutions make considerable effort to produce biodegradable packaging. Biodegradable materials can be made from biological, renewable raw materials and from fossil non-renewable raw materials.

Traditionally plastics are made from petroleum-based materials that are produced from non-renewable oil (fossil fuels). A further disadvantage is that traditional plastics are not biodegradable.

Polymers of biological origin are now being used as raw materials for plastics. These bioplastics are a new generation of plastics which are claimed to be more environmentally friendly than those made from fossilfuels. Starch - a renewable degradable carbohydrate polymer that can be purified from various sources by environmentally sound processes. It is found in high amount in plants like corn (maize), potatoes, and wheat.

Starch, by itself, has a severe limitation in that it is water soluble, and articles made from starch will swell and deform upon exposure to moisture. Therefore starch is chemically modified or blended with hydrophobic synthetic polymers – which often are not biodegradable.

4.4.7 New Innovations in Packaging of Fruits and Vegetables

Designs and material used for packaging may be different under various condition viz. controlled atmosphere, modified atmosphere, ripening chambers etc. and shipping container.

4.4.8 Pallet Boxes and Shipping Container

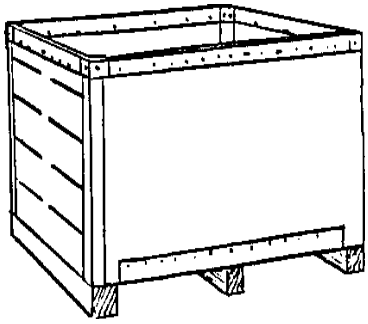
Loading and unloading is one of the very important steps in the post-harvest packaging of fruits, vegetables and root crops. Post-harvest losses can be considerably reduced by using pallets. All the subsequent handling and transportation operation become very easy once the boxes are placed on pallets. Pallets literally form the base on which most fresh produce is delivered to the consumer.

Advantages of a pallet box system:

- Less manual handling and thus reduced cost in loading, filling and unloading.
- More efficient use of available storage as compared to smaller crates.
- Increased speed of mechanical harvest.

Disadvantages of a pallet box system:

- The return volume of most of the pallet boxes is the same as the full load.
- The system requires higher investments in forklift trucks, trailers and handling systems to empty the pallet box.
- Because of the larger volumes, the produce is more easily injured during filling and unloading and the top layers will have made more movements during transport than when packed in smaller boxes.



The material can be printed to give the box a pleasant and recognizable appearance. Also the label can be included in this print.

4.4.9 Packaging Material for Fruits and Vegetable

Generally the fresh produce packed in jute bags or baskets and plastic crates for short distance transportation and CFB boxes and wooden crates for long distance transportation. The fruits and vegetables meant for super market sale are generally packed in polyethylene bags with 200 g and 500 g material.

Gunny bags	Ber, Lemon, Lime, Raw mango, Sand Pear, Sweet Orange, capsicum, cabbage, peas, potato, sweet potato
Bamboo basket	Grape, Guava, Mango, Papaya, lemon, okra, radish, carrot
Earthen Pots	Custard apple, grape
Wooden boxes	Apple, Apricot, Cherry, Litchi, Mango, Mandarin, Pear, Plum, Sapota, tomato, capsicum,
CFB	Apple, Cherry, Grape, Pomegranate and fruits for export, capsicum, chilli
Rigid plastic crates	Loose fruits for public distribution system

Packaging of fruits

1) *Mangoes:* Baskets made of bamboo with paddy as cushioning materials are used as packaging for mangoes in India due to its low cost, but they result in high spoilages of fruits. These a days, corrugated fibre boxes with

different types of cushioning materials like paddy straw, wood wool, vinylite and pliofilms wrappers, paper cuttings, newsprint, tissue paper and polyethylene films etc are used.

2) *Banana:* Conventionally bananas are transported as whole bunches wrapped with banana leaves. Use of polyethylene film bags for wrapping whole bunches for transport is found to be most suitable to reduce wastage. For export purpose bananas are packed in telescopic type corrugated fibre board boxes of different dimensions with good ventilated holes. The banana hands packed into the boxes in the lengthwise manner with their cushion resting on the bottom of the box and fruit finger tips pointing towards the lid. Stacking of these boxes is done lengthwise.

3) *Mandarins:* For long distance transport, wooden packing cases have been recommended. Here corrugated fiber board pieces are uses as liners. CFB boxes are also used with ventilation.

4) *Grapes:* 3 ply corrugated fibreboard boxes which can hold 2 to 4 kg of grapes are generally used for domestic purpose. The boxes are perforated and line with newspapers. The fruits can be protected against decay by placing sulphur treated paper such as ‘Grape guard’.

5) *Apples:* Traditionally apples are packed in wooden cases with newsprint as wrapper and pine needles or paddy straw as filler material. Now-a-days, CFB boxes provided with trays with cavities for holding apples is used. Each tray can hold 20 apples and four such trays can be placed on top of each other in the cartoon.

6) *Guava:* Guava are packed in boxes or baskets with a lining off newspapaer.

7) *Papaya:* The fruits are normally packed in baskets and individual fruits are wrapped in newspaper and the space between the fruits are stuffed with straw or saw dust.

8) *Ber:* Packed in gunny bag, cloth bag, bamboo baskets, wooden, plastic crates.

9) *Phalsa:* packed in baskets in small quantities being very perishable fruit.

10) *Pomegranate:* Usually CFB cartons are used for pomegranate packing.

11) *Bael:* Bael fruits are packed in gunny bags or plastic crates.

12) *Fig:* Fig fruits are packed in ventilated CFB boxes with fresh fig leaves as lining material.

13) *Custard apple:* Packed in earthen pots with grass and custard apple leaves as liners.

Packaging of vegetables

The vegetables are packed and transported in baskets, bags/ sacks or boxes.

1. *Tomatoes:* Tomatoes are usually packed in bamboo basket. Wooden boxes are also used of different size and shape in case of long distance transportation.

2. *Potatoes:* Commonly used packaging materials for potato are fibre mesh sacks, plastic film sacks, burlap bags. Tinted plastic bags are used to reduce light transmission to the tubers. Tubers in the transparent film bags should be protected from direct sunlight to avoid greening of the tubers.

3. *Onions:* Thin Hessian bags or bamboo baskets are used.

4. *Tuber crops:* Cassava tubers are dipped in 1% Mertect and packed in polyethylene bags and sealed to prevent microbial damage.

5. *Brinjal:* Bamboo baskets and gunny bags are used.

6. *Chilli and Capsicum:* Gunny bags, wooden boxes and CFB boxes are used.

7. *Cauliflower:* Generally packaging material are not used in cauliflower in India. Leaves protect the curd from direct exposure to sunlight. They are send in gunny bags to distant market.

8. *Watermelon:* Transported without any packing.

9. *Bottlegourd:* Baskets or crates are used.

10. *Bitter gourd:* Crates, jute bags are generally used and for supermarket sale, polythene bags are used.

11. *Pumpkin:* Baskets and gunny bags are used.

12. *Potato:* Graded and packed in gunny bags.

13. *Spinach:* Spinach is cut above root, washed, trimmed, graded and bunched or bagged.

14. *Cabbage:* Packed in crates and sacks.

15. *Pea:* Baskets, gunny bags and wooden boxes.

16. *French beans:* Wooden baskets, gunny bags.

17. *Okra:* Jute bags, baskets

18. *Muskmelon:* Transported without any individual packing in trucks.

19. *Cucumber:* Baskets, jute bags.

Root crops: Washed, graded and packed in gunny bags.

1. *Radish:* Trimmed, washed and packed in gunny bags.

2. *Carrot:* Packed in polyethylene bags after trimming tops, washing and size grading for super market display.

3. *Beetroot:* Mature roots are detopped, washed, graded and packed in gunny bags. For supermarket sale, packed in polyethylene bags.

4. *Turnip:* Gunny bags.

5. *Potato:* Graded and packed in gunny bags.

6. *Sweet potato:* Jute bags.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the primary functions of packaging material?

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2. What are the packaging materials generally used for fruits, vegetables and root crops?

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3. What are advantages of corrugated fibre board boxes over wooden crates?

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4.5 CUSHIONING MATERIALS AND WRAP

The cushioning material used for packaging fruits and vegetables are dry grass, paddy straw, leaves, saw dust, paper shreds etc. For the cushioning material to be useful, it should dissipate the heat of respiration of the produce. It should be free from infection so that it should not pass on the same to the fruit and vegetables. It is also important that the cushioning materials itself should be physiologically inactive. Moulded pulp tray, honeycomb portion, cell pack are used replacing the cushioning material. Cassia leaves as packaging materials are reported to be most effective in reducing physiological loss in weight (PLW), spoilage, retaining fruit colour and chemical quality.

Need and Importance

Damage caused by vibration and abrasion is generally a result of product movement within the package. While the damage may be superficial, it can adversely affect the market value of the commodity. Containers should not be filled either too loosely or too tightly for best results. Loose products may vibrate against each other and cause bruising, while over-packing results in compression bruising. Proper filling along with cushioning can minimize rubbing damage. Overfilling may lose all the benefit provided by suitable cushioning. Adding a simple cardboard liner to a crate will make it less likely to cause abrasion to produce. Shredded newspaper is inexpensive and a lightweight filler for shipping containers (if the ink used for newspaper print is non-toxic). Packaging materials such as trays, cups, wraps, liners and pads may be added to help immobilize the produce.

Plate 4: Use of cushioning material for packing (Source: FAO)

One of the newest trends in produce packaging is the shrink-wrapping of individual produce items. Shrink-wrapping has been used successfully to package apples, mangoes and a variety of tropical fruits. It is reported that seal packaging of individual citrus fruits film doubled the storage life as compared to control without packaging. Packaging of strawberries is done in various types of baskets and film over wraps to improve freshness and shelf-life. Shrink-wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels.

The main advantages of film wrapping of fruits and vegetables are-(i) reduced weight loss extended shelf-life (ii) minimized fruit deformation (iii) reduced chilling injury (iv) reduced decay by preventing secondary infection of fruits packed in the same box.

4.6 PRE-PACKAGING

The term “pre- packaging” covers all packaging of products in consumer units before its presentation to the end consumer. This simple technique involves cleaning, trimming, cutting of the fresh produce and packing the same in unit packages in polyethylene bags. Bean, carrot, brinjal, green chilli, root crops, leafy vegetables, and fruits like orange, lemon, banana, grape can be pre-packaged to obtain 1 to 2 times extension in shelf life in polyethylene bags under normal conditions without any refrigeration. The pre-packed produce presents better consumer appeal, longer shelf life and has considerable handling advantages in transport and marketing. The major facility required at the farm level or in orchards is a packing shed.

Pre-packaging is generally defined as packaging the produce in consumer size units either at producing center before transport or at terminal markets.

Packaging of fresh produce in consumer unit packs protects the produce against the damage and excess moisture loss.

1. It reduces the transportation cost eliminating unwanted and inedible portion of fruits and vegetables.
2. The space required for shipping and storage is less.
3. It has a better eye appeal as the produce is prepackaged in attractive film and the quality of the product can be seen from outside without opening the pack.
4. Pre packaging reduces the shopping time of the consumer as the produce is graded before being packaged.
5. It saves labour costs and produce is easy to handle.

Over-wrapping with plastic films such as polyethylene or PVC, often in the form of shrink-wrap, stretch film or cling film; bags made of paper, perforated polyethylene or polypropylene film, plastic net or cotton mesh; shallow trays of moulded pulp, paperboard, thermoformed plastic or expanded polystyrene, covered with plastic film; baskets, made of peeled wood, moulded pulp, paperboard and thermoformed or injection-moulded plastic, covered with plastic film. Among the different types of packaging films, polyethylene film finds the maximum use. Shelf life of asparagus, brinjal, okra, whole or segmented cauliflower can be increased by pre packaging in perforated or non-ventilated polythene bags.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why cushioning materials are used? What are the common cushioning materials used for fruits and vegetables packaging?

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2. Define pre-packing. Advantages of pre-packing.

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4.7 LET US SUM UP

Adopting improved packaging, handling and transportation methods can successfully avert huge post harvest losses. The product requirements, the marketing system and the personnel preference will determine the type of packaging to use.

4.8 KEY WORDS

Post harvest losses : Losses incurred after harvesting till it reaches to the consumer for final consumption. This includes losses occurring during handling, transportation, storage, distribution etc.

Packaging : Putting the material in suitable containers for better handling, transportation, and storage.

Fiberboard : Board consisting of one or more sheets of fluted or flat paper stuck to a flat sheet of paper or board or between several liners. When fluted sheets are used, it is called corrugated fibre board and when flat paper sheets are used, it is called solid fibre board.

Cushioning material : Padding material used in between the package and the product to protect against abrasion, vibration and thereby damage. The most popular cushioning materials are paper shreds, paper liner, cardboard liner, leaves etc.

Pre-packaging : Pre-packaging covers all operations include cleaning, trimming, cutting, and packaging in unit packages.

4.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISE

Check Your Progress Exercise 1

1. Post-harvest losses are losses occurring after harvest, loss of weight, quality, nutritive value, financial loss, loss of market and goodwill.

2. Packaging material is selected on the basis of: commodity, the systems of production, storage, handling, transportation, cost factor involved in producing packaging material, market requirement, consumer attitude, requirement of recycling, re-use disposal etc.

Check Your Progress Exercise 2

1. Packaging materials used serve as an efficient handling unit, protects from mechanical damage, protects against moisture loss, provides clean and sanitary storage, sales and service motivation, prevent pilferage, reduces cost of transport and marketing

2. There are many different types of package in use throughout the world. Packaging for fresh produce is of several types: Sacks, wooden crates,

carton or fibreboard boxes, plastic crates, pallet boxes and shipping containers, baskets.

3. The advantages of corrugated fiberboard boxes are: Low weight, easy handling and stacking, cushioning effect due to relatively soft walls, so minimum bruising. CFB box can be fabricated to any design, the boxes are delivered flat and assembling of boxes can be done locally, also have good printability. All they are most eco-friendly package due to their biodegradability, economical transportation

   Disadvantages of wooden crates are: Untreated wood can be contaminated with fungi and bacteria, treatment of wooden crates with paint or other chemicals may cause produce deterioration, material may be too hard or rough for produce like soft fruits, and therefore liners of a soft material may be needed, disposal of the crates after use, manufacturing of wooden crates puts an extra claim on the natural forest resources.

Check Your Progress Exercise 3

1. The cushioning material used for packaging fruits and vegetables are dry grass, paddy straw, leaves, saw dust, paper shreds etc.

2. Pre-packaging is generally defined as packaging the produce in consumer size units either at producing centre before transport or at terminal markets. Packaging of fresh produce in consumer unit packs protects the produce against the damage and excess moisture loss, reduces the transportation cost, the space required for shipping and storage is less, better eye appeal as the produce is pre-packaged in attractive film and the quality of the product can be seen from outside without opening the pack. Pre packaging reduces the shopping time of the consumer as the produce is graded before being packaged and lower labour cost.

4.10 SOME USEFUL BOOKS

1. Cornelis, C.M., Schuur (1988) Packaging for fruits, vegetables and root crops. FAO, Food and Agriculture Organization of United Nations, Bridgetown, Barbados.

2. Er. B. Pantasico (Eds.) (1975) Post harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. AVI Publishing Co.

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5. Wills, R.B.H., McGlasson, W.B., Graham, D., Lee, T.H. and Hall, E.G. (1996) Post Harvest. An introduction to the physiology and handling of fruits and vegetables. CBS Publishers and Distributors, Delhi.

UNIT 5 TRANSPORTATION OF FRESH PRODUCE AND CONTROL OF LOSSES

Structure

5.0 OBJECTIVES

After going through this unit, you should be able to:

- know which mode of transport is suitable for particular condition;
- explain how transportation can influence storage life and the quality of fresh produce;
- discuss proper loading and unloading techniques for different commodities; and
- explain the advantages of Palletisation/ unitization.

5.1 INTRODUCTION

In this unit, we will discuss about transportation of fresh produce. Transport refers to carrying a produce from one place to another. Rapid and reliable transport of fresh fruits and vegetables is of critical importance to successful marketing. The delay in transport not only affects shelf life and the quality of fresh produce, but also reduces its value in the market. Transport is an important link in the handling, storage and distribution of fruits and vegetables. The transport of produce starts from the field to the assembly points or collection centres. From these places, bulk transport is undertaken by retailers, middlemen, wholesalers, processors, exporters and importers at packing stations, storage plants and shipping points. Several modes of transport are used to move fresh fruits and vegetables from farm to final consumer. They include head load, bullock carts, bicycle, rikshaw, autorikshaw, lorry, boat, ship and aeroplane. All these methods have their own advantages and disadvantages. Head load is mostly used for moving small quantities to a nearby market. This mode of transport is usually in practice in interior areas where proper roads are not available. Bullock Carts, Bicycle, rikshaw and autorikshaw are also used for short distance transport, but adequate cushioning should be provided to the transporting material for avoiding impact damage to fruits and vegetables in such mode of transport. Boats are used for inland transport, where as ships carry produce globally. High value products and the most perishables are always air lifted to the destination market. Knowledge of these pros and cons of each mode of transportation will help us to select the suitable mode of transport for an individual commodity.

5.2 PRE-OPERATIONS AND TREATMENTS

5.2.1 Packinghouse Operation

The basic operations in a packinghouse are sorting, sizing, grading and packing. Depending on the kind of produce, additional activities may include degreening, curing, washing, bunching, chemical treatments and pre-cooling. The sequence of activities varies with different crops. These operations are essential preparatory steps for transportation and subsequent marketing.

5.2.2 Curing

Potato, sweet potatoes, taro, onions, garlic and similar crops are cured prior to storage or marketing. Injured or bruised surfaces are allowed to heal by holding for a few days at ambient temperatures. The healing process is necessary so as not to shorten storage life. Periderm formation during healing is favoured by high temperature and high humidity. In sweet potatoes, this condition is most rapid at 30^o C with an RH of 95 to 97%. Potato tubers, on the other hand are held above 20^o C for about 2 days and then at $8\,^o$ to 15^o C for 10 to 12 days at 90 to 95% RH. Another change that occurs during curing is the reduction of moisture content, especially in onions and garlic. Properly cured potato tubers have as much as 50% longer storage potential than those uncured or improperly cured. Curing also reduces rotting. Curing appeared to be generally more effective at ambient temperature than in cold storage.

5.2.3 Degreening

Degreening is the process of decomposing the green pigments in fruits usually by applying ethylene (C_2H_4) or other similar metabolic inducers to give a fruit its characteristic colour as preferred by consumers. It is applicable to bananas, mangoes, citrus and tomatoes. The length of time required to degreen a fruit depends upon the degree of natural colour break and maturity. The lighter the green colour and the more mature a fruit is, the less time is required to reduce the chlorophyll to a desirable level.

The degreening process is carried out in special treating rooms with controlled temperatures and humidity in which low concentrations of C_2H_4 (about 1:50,000) are applied. The C_2H_4 can be supplied either as the chemically pure gas in cylinders or by the old and risky method of using the fumes from the incomplete combustion of kerosene. The room is thoroughly ventilated to keep the CO_2 at levels (below 1%) that will not hinder colouring. The degreening time by this system is 24 to 48 hr. When kerosene fumes are used, the burners are placed outside the degreening room. The fumes enter the room through ducts by forced ventilation. Despite the fire hazard involved, the kerosene fumes produce better coloured fruits than pure C_2H_4, and it is suggested that this may be due to the good ventilation provided in the method. The best degreening temperature is 26°C. It has been found that higher temperatures delay degreening. The RH should be from 85 to 92%. Humidity levels high enough to cause condensation during degreening are associated with slow degreening and increase in decay. Low humidity, although it checks decay, causes excessive shrinkage, shrivelling and peel breakdown.

5.2.4 Pre-cooling

High temperatures are detrimental to the keeping quality of fruits and vegetables. However, elevated produce temperature is inevitable, especially when harvesting is done during hot days. Pre-cooling is a means of removing this field heat. The general aim is to slow down the respiration of the produce, minimize the susceptibility to attack of microorganisms, reduce water loss and ease the load on the cooling system of the transport vehicle or ship's cargo space. Various methods of pre-cooling may be used.

a) Air cooling

The temperature difference between the coolant and the commodities or packages must be reduced fast for pre-cooling to be effective. Cooling may be done fast by the use of coolants such as air, iced water, ice or vacuum. The temperature of the cooling air must not be below 0°C to avoid freezing. Prompt storage is essential to achieve the benefits of pre-cooling.

Pre-coolers using air are cold rooms and tunnels. A cold room has a very intensive air circulation, high refrigerating capacity and fairly low ceilings. The cold room is advantageous for large-scale operations. Pre-cooling tunnels are long, narrow cold rooms in which air circulates at high speed.

In forced air pre-cooling, the pre-cooler forces air through the void spaces of the fruit. The final air temperature is 0 to 1.5°C. Weight loss by forced air cooling is less than 1%. The pre-cooling operation may take 1 to 1 ½ hr.

b) Hydro-cooling

Hydro-cooling quickly extracts field heat from the produce. It has been used with advantage for leafy vegetables to retain texture and freshness. For citrus and some fruits, fungicide in the cooling water may be added to hold decay within tolerable levels. Fruits cooled with water are apparently more susceptible to decay upon warming. Sometimes it may lead to chilling injury (oranges) or damage due to water soaking (citrus). The hydro-cooling equipment consists of a large tank of iced water, a high capacity pump for circulating the water to a sprinkler system, and a conveyor belt for carrying the produce to the sprinkler.

c) Vacuum cooling

Vacuum cooling is the most rapid method of pre-cooling for leafy vegetables. The principle of vacuum cooler is evaporative cooling. At 29.9 in pressure, water evaporates at 100°C. At 0.018 in water will be vaporized at 0°C. There is 1% water loss for every 6°C reduction in temperature, therefore some water must be added to compensate for this loss.

5.2.5 Washing

As consumers demand clean produce, most fruits and vegetables are washed after harvesting. Washing improves the appearance of the produce and reduces the residues of fungicides and insecticides. Washing is not done on soft delicate and perishables fruits like strawberries. Muskmelons, cucumbers, and sweet potatoes are usually cleaned by brushing or wiping dry, rather than by washing.

5.2.6 Drying

Drying removes excess surface water from the fruit or vegetable. This is facilitated by heated air blown on the fruits or vegetables as they pass through sponge roller conveyors. Drying may also be done by a series of rotating brush dryers made of soft bristles. Minimum heat and dryer brush speed should be used to avoid injury to the fruits.

5.2.7 Waxing

Fruits and vegetables have a natural waxy layer on the outer surface, which is partly removed by washing. An extra discontinuous layer of wax is applied to the fruit, which provides the necessary protection against decay organisms. Waxing is especially important if tiny injuries and scratches on the surface of the fruit or vegetable are present. These can be sealed by wax. Waxing also enhances of the gloss of fruits or vegetables. Appearance is therefore improved, making the produce more acceptable to consumers.

5.2.8 Grading

Fruits and vegetables show considerable variations in quality due to genetic, environmental and agronomic factors. Therefore grading is necessary to get suitable returns commensurate with quality.

Grades are based on soundness, firmness, cleanliness, size, weight, colour, shape, maturity and freedom from foreign matter and diseases, insect damage and mechanical injury. Whatever the classification, the produce must possess the minimum qualifications established by the regulatory agencies.

5.2.9 Sizing

After grading, the produce is sized for uniformity. Hand sizing is useful for small-scale. For large operations, various sizing devices are used, based on either shape or weight of the produce.

For regular-shaped commodities like citrus, sizers are of many types. Longitudinal belt and roll sizers are used for some citrus varieties. Size adjustment can be made quickly from oranges to tangerines to grapefruit. Central longitudinal belt and roll sizers are of many types or variations, such as transverse roll and drop roll. The different sizes drop through the canvas distribution belts and are transported to the packing stations. Perforated belt sizers consist of a belt or chain having certain size holes or meshes in each section. Commodities may be moved about on the sizers. Shaking screens with varying sizes of holes can be used for sizing. Fruits can be vibrated along the screen and collected in different sized holes. For small products such as peas and cherries, a rotating cylinder may be used. The surface of the cylinder contains many holes or slots formed by metal rods. Commodities such as cucumbers, pineapples and large root vegetables are sized by diverging belt or rope grader. For commodities with irregular shapes, sizing is done by weight of the produce.

5.2.10 Disinfestation Treatment

One of the most important pests in crop production are fruit flies. Papayas, mangoes, melons and many other fruits are highly susceptible to fruit fly attacks. Disinfestation treatments do not vary much among fruits. The disinfestation methods for export of papayas include the vapour heat and EDB fumigation treatments. An irradiation treatment needs the government clearance before use.

The vapour-heat treatment, in addition to disinfecting the fruit, controls storage decay, but it is a relatively expensive operation in terms of initial investment for equipment and operational cost. Further, it takes a long time of approximately 15-20 h, and even in properly treated fruits, vapour heat causes a reduction in the aroma of the fruit pulp.

The fumigation treatment is more economical than the vapour-heat treatment. The entire treatment time is only about 4 hr, much less than that required for the vapour-heat method. Furthermore, most of the fruits are not damaged by the treatment, and storage decay is controlled. Cold treatment is also used for this purpose but in case of fruits where there is no injury at low temperature.

5.3 FACTORS AFFECTING TRANSPORTATION OF FRESH PRODUCE

Many opportunities for damage to fruits occur during its transport from field to the destination market. Impact bruises can occur when bins are dropped during loading or unloading. Stacking of overfilled containers may cause compression bruises in fruits and vegetables. Abrasion or vibration bruises may occur when fruits move or vibrate against rough surfaces or each other during transport. Bruises and injury reduce saleability of the fruits and vegetables and reduce the quality and shelf life by enhancing senescence.

The time of harvest or maturity of a product can influence the temperature required during transit. During harvesting and packaging, several factors may affect the physiological behaviour of the commodity during transit. These are (a) maturity at harvest, (b) field temperature and humidity at harvest, (c) mechanical injury, (d) time between harvest and cooling, (e) type and rate of pre-cooling, (f) sanitation of packing facilities and (g) use of brushes, dips, sprays and fumigants.

Factors affecting transportation depend upon

- Product handling
- In-transit temperature and humidity
- Air circulation and ethylene removal
- Compression/abrasion during movement

Poor handling of produce during loading and unloading of transport vehicle results in high post-harvest losses. In our country, containers, rail wagons and road vehicles are loaded by hands, implying that each package is manually lifted and dropped 4-10 times between harvest and consumption. Further, most often casual labours are hired for this work. As casual labours have no or little knowledge of handling fresh fruits and vegetables, the risk of quality deterioration of fruits and vegetables increases.

Each commodity must be transported under optimum conditions of temperature and humidity. Fruits should be protected from high temperature in the field after harvesting. Wherever possible, harvested fruits should be moved to the shade until transport. During transport, speedy handling is done for the protection of the commodity.

Fresh fruits and vegetables in packages have two environments, one inside the package and other one outside. Controlling outside environment does not necessarily control the environment inside the package. Mostly fresh produce is packed in corrugated fibreboard, which is a poor conductor of heat. When the produce generates heat and gives off water, it may affect the packaging material resulting in collapse of carton. When such a package is transferred in cold environment, and if the rate of heat production exceeds the rate of heat transfer, the product will get hotter, and the increased respiration rate will result in higher vapour production. If the walls of package become colder than the air inside the package, moisture given off by the produce can condense on the inside of package walls resulting in collapse of carton. Therefore, circulation of air inside package is important to maintain uniform temperature through out the package. Further, air circulation helps in removal of ethylene from the produce, which is necessary for maintaining the optimum quality of fruits and vegetables.

Packing and mode of transport selected should be such that it causes no or minimum vibration and bruising injury to the product. Vibration and bruising are the major causes of spoilage of fruits and vegetables during transport. To avoid vibration and bruising injury, cushioning material should be used.

Shipping containers

Packaging for shipping and handling requires appropriate engineered containers to protect produce from bruising, vibration and the weight of other stacked containers. The ideal pack consists of a tight fill without a bulge in a lidded container having sufficient stacking strength to protect the contents under all handling conditions. Any shipping container should be designed to meet the specific requirements of the particular fruit or vegetable.

In more developed countries, many shipping containers are used only once, and are not returned to the shipper. In less developed countries, baskets and boxes are often returned for reuse.

Shipping containers should be labelled with large print to specify the commodity, variety, weight or count, grade and source.

Wooden containers can be the strongest and most rigid type of shipping container, but strength depends on the thickness of materials used. Common types include: nailed wooden boxes and crates, wire bound boxes and crates, ply wood boxes, bulk bins or pallet boxes and wooden pallets. Pallets are platform devices used as a base for assembling, storing and handling or shipping other containers in a unit load. The base may be a 2-way or 4-way type to allow entry of types of powered forklift or hand pallet trucks.

Fiberboard (corrugated) cartons are becoming popular for shipping both tropical and subtropical produce. Their light weight and low cost are advantages. However, they have the disadvantage that some types absorb moisture and lose strength and thus stacking height may be limited in areas or in storage where RH is high. The strength of fiberboard cartons may be increased with stronger base materials, with internal dividers, extra liners or by using full telescope type cartons with two outer walls. Strength and moisture resistance may also be aided by resin and paraffin wax coatings. Waxed cartons filled with produce may be hydro-cooled and top iced or have packaged ice enclosed.

Fiberboard cartons are also common for mature green tomatoes and avocados and as master containers for consumer-packaged vegetables, such as cellophane-wrapped cauliflower, trays of tomatoes and polyethylene bags of carrots or other root crops.

Mesh, burlap and multi wall paper bags may be used to ship onions, cabbage and potatoes. Some types of paper bags have special wet strength properties that allow use of package ice for non pre-cooled carrots and sweet corn.

Bulk packs

Bulk boxes or pallet bins occasionally are used as shipping containers for fruits and vegetables going to terminal market warehouses to be repacked in consumer packages. Fruits and vegetables for processing, such as tomatoes, carrots, sweet potatoes, citrus and pineapples are often shipped in bulk boxes. Bulk boxes may be constructed of plywood, sawn lumber, wirebound veneer, fiberboard, wire or combinations of these materials.

The advantages of bulk boxes over field boxes of equivalent capacity, are lower cost, rapid loading of transport vehicles and replacement of costly manual labour. Also with bulk boxes, storage or warehouse facilities can be utilized more fully and properly designed bins easily withstand stacking loads.

Consumer packages

Consumer-sized packages for produce consist only of having a supply of paper or plastic bags available for customers to select, package and weigh their purchases. With such packaging, standard sized units are packed after washing or grading. Each unit is labelled as to commodity, weight or count, brand, source and other information and the consumer units are packed in master shipping containers usually made of fiberboard.

Consumer packages are of the following types: (a) bags made of paper, film or cotton or plastic mesh; (b) trays of moulded pulp, paperboard, plastic or foamed plastic; (c) folding paperboard cartons, sometimes with a clear plastic window or with dividers for individual fruits; and (d) small rectangular or round baskets, punnets or cups of moulded pulp, plastic, veneer or coated or waxed paperboard. Moulded vacuum-formed plastic trays may be made of polystyrene or polypropylene. Foamed plastic trays are usually of polystyrene.

Stacking containers

The nature of the container and the manner of stacking are important factors that influence cooling in storage or transport. An elaborate system for air distribution is useless if poor stacking prevents airflow; air follows the path of least resistance. Generalizations on stacking arrangements are difficult with the large variety of containers in use for different commodities. A distance of 2-3 inches between rows of boxes or cartons is desirable. Rows should be laid out so that the direction of airflow is along rather than across the rows. Loaded pallets or pallet boxes in storage should be formed in straight lines to provide about 4 to 6 in of space between rows.

Special precautions should be taken in stacking containers on pallets so that as much container surface as possible is exposed to moving air to speed cooling. With fiberboard cartons, cooling may be more difficult because, having no bulge or slats, as do many wood containers, they may be stacked too tight. Produce in unventilated cartons cools very slowly and often stays appreciably warmer than the surrounding air during storage. Bulge packed cartons or boxes should not be stacked so that the weight rests on the produce, but should be stacked on their sides; or wood cleats or stripping may be needed to avoid crushing or bruising the products.

5.4 MODES OF TRANSPORT

The mode of transport of fresh horticultural commodity depends on distance to market, perishability and value of product, and the cost of transportation method. Before selection of the mode of transport a consideration must be given to

- Kind, variety, and condition of commodity
- Distance to market
- Price of the commodity
- Transit environment
- Cost of the transport

Different modes of transport used for horticultural crops include:

- Road transport
- Rail transport
- Water transport
- Air transport

Road transport

The most common transport used world wide, and because of its flexibility, door-to-door delivery, fast, easy to load and unload; and general improvement in road conditions its use has been in rise. However, this method is energy intensive, expensive and needs a relatively developed road infrastructure.

In our country land transport is mostly done with open non refrigerated trucks. It results in high losses of produce due to warming. But for short distance transport natural ventilation is always sufficient to prevent losses due to heating. It is advisable to use refrigerated van for long distance transport.

Need and Importance

Transport by road is the most important, and will continue to be the predominant mode of transport in the developing countries. It offers the benefits of great flexibility in operation, suitability for short hauls and possible door-to-door service with all the implied conveniences of loading and unloading. However, it depends upon road conditions, transport service available and organization of transport services. Connecting roads may be inaccessible during rainy months and bridges may become unsafe. Because of inadequate roads, high freight rates may be charged to transporters.

Another difficulty is that in produce transported by public vehicles, handlers and passengers have no regard for the safety and quality of the product. Often, if commodities are carried together with passengers, public vehicles deviate from direct routes to get more passengers, and there is delay in transport.

For more systematic and advanced transport facilities, e.g. refrigerated truck vans, are required. Although, use of modern facilities will increase the cost of the product in the markets, it can be compensated by supply of quality product to the consumers. For short trips, the product can be washed, disinfected, dipped in cold water and immediately placed in ice cold insulated vans. Sometimes the short periods transport can be done in a non-refrigerated but pre-cooled vehicle also. If the distance to the market is such that product temperature would be undesirably high despite provision for pre-cooling and insulation, dispensable refrigerants such as ice, dry ice, eutectic solutions or liquid nitrogen may be used. Application of these refrigerants depends not only on the duration of trip and transport temperature but also on the cost and availability of the refrigerant. If still longer transport time is expected, then the use of mechanical refrigerating machinery in the vehicle should be done.

The fundamental considerations for transport over short and long distances are as follows:

1. In transport of short duration, the product should be protected against mechanical injury and exposure to extreme temperatures. The produce should be moved in a direct and consistent direction as much as possible and should not retrace its tracks.

2. For transport over long distances, there is an added risk of product deterioration due to excessive heating and wilting, inception of decay causing organisms, chilling, softening of succulent commodities or ripening of fruits. Hence, provision for more sophisticated facilities is recognized more than ever and is one of the many urgent problems in the tropics, despite the high capital investments involved.

Rail transport

Although slower than road transport, it can provide vibration free ride at relatively less cost. However, this system of transport is declining significantly due to its less versatility and inaccessibility with production site. For short distances the rail transport is usually completed within 5 hour, which can help in avoiding refrigeration. For long distances, the rail transport is often preferable to road transport provided it is frequent and dependable. Refrigeration is needed and is more easily arranged by rail than by road. Because it is imperative to protect the product during this long shipment, refrigeration principles and practices must be followed.

Water transport

River transport is slow, but it can be used for non-refrigerated commodities. Sea transport is usually used for long distances, and use of refer containers offers a cheap method of transport in comparison to air transport.

Facilities of boats and vessels should be made available for river and sea transport. Frequent and improper commodity handlings often offset any cost advantage of water transport. With the advances in containerization the improvements in the international sea transport are happening. Refrigerated vans or trailers are now being used, which are crane-lifted to the ship, and greatly minimizing dock-to-ship handling.

Air transport

One of the most dramatic developments in the transportation of perishables is airfreight. Air transport is mostly done on passenger airplanes with a little quantities of crop being carried on cargo. Products can be sold in markets thousands of kilometers away only a day after harvest. This transport is relatively fast, making it suitable for very perishable commodities, but cost incurred in transportation is very high.

Use of air transport is very limited despite its speed due to:

a) the high cost per kg,

b) disruption of flight schedules due to bad weather,

c) traffic in handling of produce at air terminals,

d) the distance from the production or consignment centres to the airport and then from the airport to the market upon arrival at destination,

e) uncertain amount of cargo space available on scheduled flights and

With the advent of jet and jumbo planes, however, air transport offers vast possibilities. The lower operating cost per ton/km with even faster schedules has already resulted in an increase in air-transported fruit and vegetables. Prospect of air transport should not be evaluated solely on the basis of reduced operating cost, but also on the gains from premium consumer prices due to better quality of vine- or tree-ripened produce. Airport product-handling facilities and ancillary services are expected to improve as a result of current developments in aviation technology.

5.5 LOADING AND UNLOADING

It is very important to have proper loading and unloading procedure, as both the steps can damage the product integrity and render it unfit for human consumption. The product must be packed in appropriate container. Weak packages and their enclosed contents are more prone to damage during transport. There must be minimum damage to the product during loading and unloading operations.

5.6 PALLETISATION/ UNITIZATION

In advance countries almost all horticultural packages are unitized for handling. The packages must be designed for secure palletisation. The package must withstand expected stresses in the stacking column. If the packages are cross-stacked, their vents must be located on both ends and sides to allow air circulation through all packages on the pallet. The package dimensions must be compatible with pallet dimensions.

Some advantages of palletization include:

a) Savings in handling costs averaging 40 to 45%;

b) reduced handling time;

c) fewer personnel accidents by substituting mechanical or manual handling and lifting;

d) more efficient utilization of storage space;

e) reduced product damage; and

f) uniform stacking of produce.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the different modes of transport used in our country?

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2. Why air circulation during transport is important?

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3. How vibration and bruising injury can be avoided during transport?

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4. In your view what mode of transport should be used for high value fresh horticultural produce for export market and why?

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5. What different modes of transport can be used in for Delhi market?

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6. Why proper loading and unloading procedures are important?

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7. How palletisation helps during transport?

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8. In your view which mode of transport should be used for fresh horticultural produce for export market?

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5.7 LET US SUM UP

Transport of fresh produce is necessary to make sure its availability to the consumers. Although several methods of transport are available, a suitable method is selected based on value of the crop and distance of market. It is of paramount importance to have proper handling before and during transport to avoid any injury to the produce and to have more shelf life.

5.8 KEY WORDS

Transport	:	Movement of the product
Ethylene	:	A colourless flammable gas which stimulates ripening
Respiration	:	Process of hailing oxygen and exhaling carbon-di-oxide
Pre-cooling	:	Process of cooling fruits and vegetables immediately after harvesting
Waxing	:	Coating of fruit surface with food grade paraffin
Refer container	:	Containers used for transport of fruits and vegetables, which can be cooled to refrigerated temperature.
Perishable	:	Commodity having short life cycle
Pelletization	:	Stacking the product in a definite area as a single unit
Unitization	:	Stacking the product in a definite area a single unit

5.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:

   - Road
   - Rail
   - Ship
   - Aeroplane

2. Your answers should include following points:

   - Temperature regulation
   - Ethylene removal

3. Your answers should include following points:

   - Proper cushioning
   - Infrastructure development

4. Your answers should include following points:

   - Air
   - Fast quality deterioration

5. Your answers should include following points:

   - Road
   - Rail

6. Your answers should include following points:

   - Impact injury
   - Quality deterioration

7. Your answers should include following points:

   - Uniform stacking
   - Proper ventilation
   - Avoids injuries

8. Your answers should include following points:

   - Air
   - Sea

5.10 SOME USEFUL BOOKS

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UNIT 6 CLEANING, SELECTION, SORTING, GRADING AND PACKAGING

Structure

6.0 OBJECTIVES

After studying this unit, you should be able to:

- understand different operations in handling of fresh fruits and vegetables;
- learn usefulness of these operations in maintaining quality; and
- know about containers and packing line.

6.1 INTRODUCTION

After harvesting of the crop and before marketing or storage of the produce several operations like cleaning, sorting, grading *etc.* are done. These post-harvest operations increase attractiveness, maintain quality for a longer period and increase storage life. In the developed, countries these operations are done in the packing houses, therefore are called packing house operations. In India these operations are not usually done except in case of fruits of commercial importance. In this chapter, we will learn these operations and their usefulness in post-harvest management of fruits and vegetables.

6.2 CLEANING

Soil and other materials are removed from the surface of fruits and vegetables by washing, brushing or sometimes both to improve their appearance, to prevent wilting and to remove inoculums of pathogen causing post-harvest diseases.

6.2.1 Washing

The produce is washed with clean water usually by putting in a water tank having a continuous flow of water and agitation. Use of chlorinated water containing about 200 ppm of chlorine helps in surface disinfection. If the water is recycled, chlorination is must. This helps in checking spread of the diseases especially bacterial diseases. Washing under a shower with pressurized water is more helpful in removing soil from root vegetables like carrot, radish, turnip *etc*. Rotary drum machine or barrel washer is used for potato and other root vegetables. Brush washers take care of cleaning of individual fruit or vegetable. After washing excess water should be removed. This can be done manually or with a machine.

6.2.2 Dry Cleaning

This is done with the help of machines with brushes and is used in crops that can be adequately cleaned without water. Brushes loosen any leaf or lightly attached particle and give a polishing effect with the option of aspirating afterwards. Aspirators are simple machines consisting of a vibrating mesh belt conveyer which carries the produce across the upward vertical air blast. Any light chaff or leaf is lifted off and removed. Root vegetables often need some degree of abrasion before aspiration. Machines are available with spring or rubber or spiral rollers for this action.

6.3 TRIMMING

Removal of unwanted leaves, stems or roots prior to packaging and storage is done in vegetables like lettuce, cabbage, cauliflower *etc*. It improves attractiveness of the produce and also reduces storage space by eliminating unwanted material.

6.4 SELECTION

The desirable characteristics of a fruit or vegetable are dictated by its intended use. Since the main outlet of fruit and vegetable is usually the fresh market, the acceptability of the produce is determined by consumer preference, attractiveness and organoleptic quality. The same criteria do no necessarily apply to the raw materials for processing. The processor is primarily interested for colour, flavour and texture. The grower is more concerned with least cost of cultivation, high marketable yield and maximum profit.

All these aspects constitute quality of the produce and are important for selection of the commodity. Quality may, therefore, be defined in terms of end use. Important factors in quality for the consumers are (i) appearance including size, shape, and colour (ii) condition and absence of defects, (iii) texture, (iv) flavour and (v) nutritional value.

Overall quality of the fresh produce cannot be improved after harvest. Controlled ripening can improve the colour of the produce like tomato, mango, banana *etc*. or modified storage environment can extend the storage life, but only as much as the pre harvest conditions of the crop allows. Thus the ultimate market quality of the produce will be influenced by the growers as soon as the crop or the variety is selected. If there is no domestic or nearby market for a particular crop and the grower has no facility for allowing distant transportation, there is no point in growing that crop. It is often more profitable for the growers to grow unusual vegetables like lettuce, broccoli, Brussels sprout, cherry tomato, gherkin, yellow or red capsicum *etc*. and fruits like strawberry, Kiwi *etc*. and sending them to metropolitan markets for meeting the requirements of economically higher strata of the society and foreigners. Off-season production of fruits and vegetables also fetch a good return to the grower. Production of vegetables like okra, bittergourd, cucumber *etc*. during winter and capsicum, tomato *etc*. during summer are very remunerative and can fetch higher return in metropolitan cities.

Selection of a particular variety to be grown will depend on a few aspects as discussed below.

a) The variety should match the consumer preferences of the market to be served. This is especially true in case of vegetables like brinjal, tomato and onion, and fruit like banana. In brinjal, shape (round, long, oblong), colour (purple, green, white, variegated) and size (large-round, small-round) determine the preferences among the consumers of different regions. In tomato, sour and juicy varieties are preferred in some areas over non-juicy firm varieties. In some areas white onions are preferred over other types and in some multiplier onion is preferred over the common types. In areas where red bananas are preferred, the yellow ones do not fetch good price.

b) Good seed of genetically pure variety is very important because it will ensure uniform produce of proper maturity at harvest, minimising greatly post harvest problems. This important aspect is very often overlooked.

c) In case of hybrids especially of tomato, long distance transportation could be more remunerative and fetch higher return. Thick skinned (pericarp) hybrids fetch higher prices in the markets located in distant places as they are less susceptible to damage during transit as compared to the varieties with thin pericarp.

d) If the crop is grown for processing, the variety should be selected as per specific requirements of the processing industry. In mango, varieties with more pulp content like Totapuri is preferred for processing. In tomato, varieties with high total soluble solid (TSS) are preferred for manufacture of tomato products. In onion, white varieties with high TSS are required for dehydration.

6.5 SORTING

Sorting is almost entirely a manual operation because human sight and dexterity have not been replaced satisfactorily by machines. Sorting is generally done in a packing house as a part of a cleaning, sorting and sizing on packing line. The purpose of sorting is (i) to remove items which are under size, over or under ripe, misshapen and damaged, and (ii) to meet requirements of a grade established by the centre, state or marketing agreement authority. Sorting improves attractiveness of the produce and reduces the quantity to be handled during subsequent operations like grading, packaging *etc*., by eliminating unwanted materials. By removing the damaged produce before hand, it reduces loss due to post harvest diseases during transport and storage.

Culled fruits and vegetables which do not conform to the specific quality attributes may be utilized for extraction of essential oil and pectin from citrus peel, starch from mango seed kernel and potato, natural colour from grape, *jamun*, p*halsa*, carrot *etc*. They can be effectively utilized for production of animal feed. Some of the fruit and vegetable wastes can be usefully diverted for biogas generation and making field manure.

6.5.1 Sorting Equipment

The produce for sorting generally moves over a belt or roller conveyor. A roller conveyor, which turns the produce as it moves forward, is preferable to a belt because it allows the sorter to see all sides of each item. Each sorter on the line picks out those products, which are not suitable for high marketing. Sufficient light above the sorting table is also essential for high efficiency of the operation.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why cleaning of horticultural produce is done? What are different methods of cleaning?

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2. What do you mean by selection and sorting? How improvement of quality of the produce to be marketed is brought about by sorting?

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6.6 GRADING

Buying of fruits and vegetables is done on the basis of grade and size. Fruits and vegetables show considerable variation in quality due to genetic, environmental and agronomic factors. Grading is necessary to get suitable returns commensurate with quality. Most countries have their own set of standards for domestic trade. Grades are based on soundness, firmness, cleanliness, size, weight, colour, shape, maturity, freedom from disease, mechanical injury, insect damage *etc*. Usually there are two to three grades for most of the products as extra grade, grade 1 and grade 2. Grading may be done manually or mechanically.

6.6.1 Grading Equipment

Grading machines fit into four main categories depending on the quality to be graded, viz., size, mass, colour and profile. Other machines that have been considered include those which measure a range of acoustic and optical properties, firmness and resilience. Size graders may incorporate an element of shape by which it can select fruits or vegetables with specific shape. Size graders are available in several different forms which have different numbers of contact points and different shaped apertures. The major limitation is that in most graders measurement of the produce is two dimensional and items may be upended to pass through. Other important aspects are utility of the machine to handle different crops, gentle handling of the produce and initial capital cost.

Different types of available graders suitable for individual crop are discussed below:

Screen grader

In this machine the produce is conveyed along with a series of belts having holes of different sizes. Any item smaller than the hole size of the belt drops down onto a chute or crosswise conveyor below. The machine will have two or three belts with holes of different sizes. The first belt will have smallest holes to remove the smaller sizes first. The size of mesh (hole) increases with subsequent belts and the largest fraction would be the carry-over from the larger mesh belt. The shape of the hole in the belt is usually square, but hexagonal are also available. This is usually a harsh method and is not suitable for fruits like apple, peach etc., which require gentle handling. Continuous shaking of the belt provides easy cleaning of the holes and faster movement of the produce.

Barrel screen grader

These graders have cylindrical screens in place of flat belt screens as in screen grader. A typical barrel grader will have three cylindrical screens. The smaller holes are at the upper end of the sloping barrel and the larger holes are at the lower end. The barrel is tilted at about 5^o so that the produce passes down by gravity. This type of grader is suitable for onion, carrot, beet, citrus, gladiolus bulbs *etc*.

Diverging belt grader

The grader operates on the basic principle of diverging elements. The produce is conveyed along a narrow channel, the width of which increases gradually as it travels along until it is so wide that the produce drops through the gap by gravity on a belt or chute below. The smaller ones drop through first and the larger ones are carried further. Graders working on this principle are available for different crops.

Roller grader

This is working on the principle of diverging elements where the produce is conveyed by a series of rollers which get wider and wider as it moves along. The smaller fruits or vegetables drop down first and the larger ones are carried forward. The main drawback of this machine is that it cannot differentiate between a longer and a shorter produce. It is suitable for spherical shaped fruits like orange, apple, tomato *etc*.

Link grader

It works almost in the same way as that of the roller grader. But instead of rollers, it carries the produce between the links which move along diverging rails. It gives more precise grading than the roller grader.

Iris grader

This is the grader where round hole mechanism has been used, and instead of having only two links, it has a set of elements arranged in an iris with a central hole. The irises pick up one fruit each at the entry point of the machine and then move along a track. The irises widen as they move along providing increasing diameter of the hole to the fruit. The fruits while passing through the holes drop at the appropriate place.

Mass grader

This is different from other grades where the produce is graded on the basis of weight, whereas most fruits and vegetables are bought and sold by both size and weight.

6.6.2 Optical Methods of Grading

Several crops are bought on the basis of colour, for e.g. tomato, pepper and apple. The usual colour to be sensed is green, yellow and red, which can be readily sensed by photoelectric techniques by the grader. The principle of operation is that light is taken from at least two sources at the fruit or vegetable and the reflected light is received by photoelectric cells. A reflector behind the item shows one of its colours, for e.g. a red apple might have a red reflector. In this case, the sensor or photoelectric cell would not recognise any difference between the apple and the reflector. If a green apple comes, it will receive a different reflected signal and the green one will be removed mechanically from the lot.

6.6.3 Manual Inspection and Grading

In spite of advances in the development of sophisticated equipment for grading, majority of fruits and vegetables are graded manually by hand and eye, even in the developed countries. Some fruits and vegetables have unusual physical characteristics, which demand manual grading. For example, grapes and bananas have unusual shape and invariably sold in bunches or clusters. Machine grading is not possible in such cases. Bananas are to be carefully graded in terms of ripeness, colour, length and blemishes, all of which are carried out manually.

Manual inspection is usually done by workers who sit along side a moving flat belt or preferably a series of rollers so that the produce is turned over continually in order to see each side of it. The workers inspect and group the produce into different grades.

6.7 PACKAGING

Assembling of the produce into convenient units for handling is called packaging, and it provides protection to the produce during transport, storage and marketing. Sometimes the produce is enclosed in smaller individual packages of consumer units (Wraps, bags, trays etc.), which is called as pre-packaging and then the individual units are put into the bigger container.

6.7.1 Pre-packaging

Many materials are used as pre-packages for different produce *e.g.* plastic films like polyethylene, polypropylene, polyvinyl chloride and polystyrene, nylon net bag, paper bag, pulp tray, open-weaven hessian bag *etc*. Plastic films have heat shrink characteristics and can be used for shrink wrapping under controlled temperature and tension in a specialized machine. They may be used separately or as wrap over moulded polystyrene or pulp trays. The produce in a package (usually consumer unit) should be of comparable weight, size, maturity and grade. Some packaging involves enclosing a single product unit (a curd of cauliflower or a head of cabbage), while in other packaging, several product units are enclosed in a single consumer unit (radish, carrot). Packaging is done manually or by a machine. However, such additional packaging increases cost. Therefore, it must be compensated by reduced wastage and increased selling price. A given quantity (count or weight) of individual packages is then packed in a larger container for transportation and distribution. Such containers may be bags, wooden boxes, bamboo (or other plant twig) basket, corrugated fibreboard boxes, plastic crates *etc*.

6.7.2 Qualities of a Package

Modern packages and packaging should meet the following requirements.

i) They should be strong enough to protect the contents during handling and transport.

ii) They should stabilize and secure the product against movement within the package during handling.

iii) The packages should maintain shape and strength under high humidity and when wet.

iv) They must facilitate rapid cooling of contents and/or offer a degree of insulation from external heat or cold.

v) They should have sufficient permeability (in case of plastic films) to gases and vapours produced during respiration by the contents.

vi) The packages should be cost effective and attractive and amenable for containing details of printing the label.

vii) The material of construction must not contain chemicals which could be transferred to the produce and be toxic to human being.

viii) The security of the package or its ease of opening and closing might be important in some marketing situation.

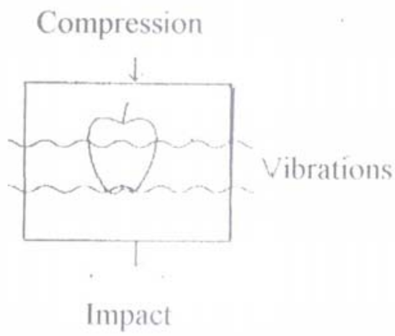
ix) The package might be required to aid retail presentation.

x) The package might need to be designed for ease of disposal, re-use or recycling.

It is becoming important to standardize the size and shape of the packages for unitization (*e.g.* use of pallets) and mechanical handling (*e.g.* fork lifting). An optimum length to width of the package is about 1.5:1.0. As per recommendations by the International Labour Organisation, 30 litre (about 20 kg of produce) and 15 litre packages are becoming standard for fruits and 36 litre packages for some vegetables.

6.7.3 Prevention of Mechanical Damage

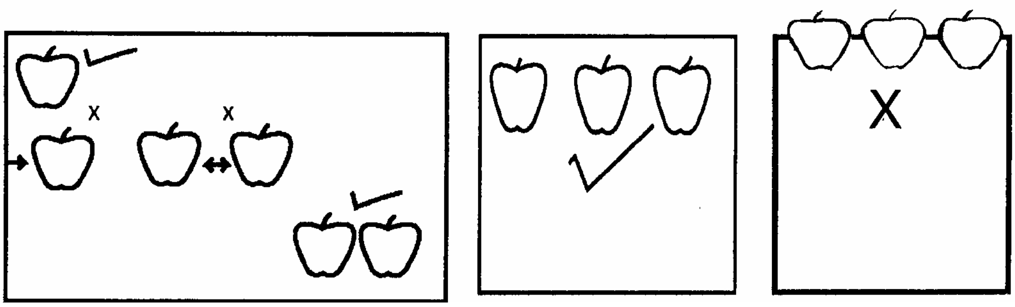
- Four different causes of mechanical injury are
  - cuts
  - compression
  - impacts
  - vibrations (rubs)



- **Cuts:** Handle produce carefully. Avoid cuts.
- **Compression:** Except certain so called 'hard' vegetables such as pumpkin, potato or onions, the package must be strong enough to carry the stacking loads, otherwise there will varying degree of compression bruising.
- **Impact:** Dropping of packages or impact shock in transport
- **Vibrations:** Common during transport, causes abrasions ranging from light rub marks to removal of not only skin but also some of the flesh. All these injuries turn brown during exposure of the material to air. The produce is disfigured and its market value is reduced. These injuries are avenues of infection, increase respiration, enhance the rate of deterioration and cause immediate loss of edible material because of the need to trim damaged portions.

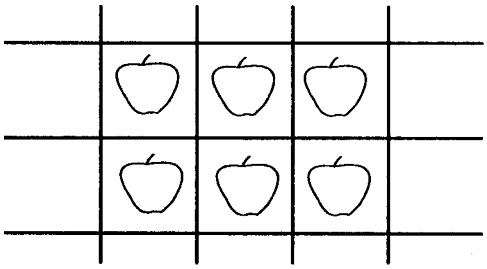
Avoiding vibration injury

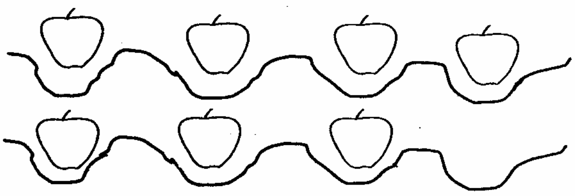
- Individual specimen should not move with respect to each other or the walls of the package.



- Packaging should be full without overfilling.
- Packing too tightly increases compression and impact bruising.

- Individual wrapping.
- Isolating each piece as in cell pack.



- Tray packing 

6.7.4 Some Important Aspects

There are some other important considerations in packaging which are given below:

- Cushioning materials are provided to absorb vibration and compression during transport and to prevent movement of the produce in pack or packaged units within the container. Various cushioning materials such as paper shreds, thermocole, dry grass, paddy straw *etc*. used as bottom pads or between layers of fruits and vegetables are effective in absorbing impact and reducing bruising of the produce. The cushioning material (i) should have ability to dissipate the heat of respiration of the produce, (ii) should be free from infection which is likely to be passed on to the produce, (iii) should not injure the soft fruit, and (iv) should be physiologically inactive.

- Water loss of the produce in packages can be reduced by using plastic films with ventilating holes as pre-packaging or consumer packaging material. Ventilating holes (small perforations) prevent condensation of moisture inside packages and also allow some gas exchange for respiration, thereby preventing anaerobic respiration which otherwise would have caused off-flavour development. Polyethylene film lined corrugated fibreboard boxes with ventilating holes serve as a good container of pre-packaged units for fruits and vegetables.

- Fruits on ripening release ethylene gas which causes ripening of other fruits in the package. If early ripening is not desired, it is necessary to remove ethylene developed within the packages as quickly as possible. This is done by ethylene scrubber using blocks or sachets of high surface area materials *e.g.* foam, blotting paper *etc*. impregnated with potassium permanganate solution. Potassium permanganate oxidises ethylene to carbon dioxide and water. Some commercially formulated material like Purafil is available for scrubbing ethylene from the packages.

6.7.5 Packing Line

The method of packaging depends on the type of the produce, size of the package and operation time. High value crops such as avocado, peach, apple and kiwi fruit are often packed by hand. Hand packing helps in proper orientation of fruits in a box and thus improves overall protection and appearance. Large scale operations are often done in a packing machine. The automatic machines are arranged in multiples up to about 10 along a belt conveyor. The produce is fed into the reception hopper from where it is elevated and distributed to different machines. A gate linked to each filling station deflects the produce down a chute and into a tilted, waiting box. As the box becomes full, it lowers gradually and the preset weighing machine closes off the feed gate. The box is then carried on a short roller conveyor onto a further main conveyor with all boxes from other machines. Each box takes about one minute to fill and needs no supervision. The boxes then pass through an automatic box sealing and printing machine. Though this is a convenient method of packaging, it causes damage to sensitive fruits. It is, therefore, popular for more robust fruits like citrus and for fruits for local market. Automatic pallet loading by palletizer may then follow, or else the boxes may be manually stacked for transport.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you mean by grading?

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2. What is packaging and what are qualities of a good package?

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3. How water loss from and anaerobic respiration of the produce and ethylene accumulation inside the package are prevented by proper packaging techniques?

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6.8 LET US SUM UP

In this unit, you have read about post harvest operations like cleaning, trimming, selection, sorting, grading and packaging of horticultural produce. It has given you an idea of different machines used for grading and packaging.

6.9 KEY WORDS

Cleaning	:	Removal of soil and other materials from the surface of the produce by brushing or washing.
Sorting	:	Removal of under size, over or under ripe, misshapen and damaged products from the lot to meet requirements of a grade.
Grading	:	Grouping of the produce into different lots on the basis of size, weight, colour, shape, maturity.
Packaging	:	Assembling of the produce into convenient units and it provides protection to the produce during transport, storage and marketing.

6.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Purpose and methods of cleaning of horticultural produce

2. Your answer should include the following points:

   - Definition of selection and sorting
   - Improvement of the produce by sorting

Check Your Progress Exercise 2

1. Your answer should include:

   - Grading and its importance

2. Your answer should include:

   - Definition of packaging
   - Qualities of a good package

3. Your answer should include:

   - Methods which help in preventing water loss and anaerobic respiration of the packaged produce
   - Use of ethylene scrubber

6.11 SOME USEFUL BOOKS

1. Kader, A.A. (ed.) (1992) Post-harvest Technology of Horticultural Crops (2nd edition), University of California, Berkley.

2. Thompson, A.K. (2003) Fruits and Vegetables: Harvesting Handling and Storage, Blackwell Publishing, U.K.

3. Wills, R., McGlasson, B., Graham, D. and Joyce, D. (2004) Post-harvest (4th edition), CAB International, U.K.

UNIT 7 TREATMENTS: PRE-COOLING, CURING, INHIBITION OF SPROUTING AND FUNGICIDE APPLICATION AND RIPENING

Structure

7.0 OBJECTIVES

This unit shall analyze the problems related to checking post harvest losses of fruits and vegetables. Here the issues of appropriate post harvest treatments with particular reference to curing, pre-cooling, checking sprouting and rotting of fresh fruits and vegetables will be discussed.

After studying this unit, you should be able to:

- cooling requirement of horticultural crops and pre-cooling techniques;
- concepts of curing;
- effects of sprouting and its inhibition;
- waxing and surface coating of fruits and vegetables;
- post harvest disease management and fungicide application; and
- control of ripening.

7.1 INTRODUCTION

Ever since the civilization of mankind, efforts have been directed towards accumulating and storing foods when they are in plenty in order to meet needs during the days of scarcity. In case of food grains not much problem was faced due to nature's noble way of reducing the moisture level as the grains mature and further drying after harvest. However, in case of fruits and vegetables, long term storage in their fresh form was not possible (until development of modern methods) primarily due to their high degree of perishability owing to high moisture content of these commodities at the time of harvest.

Storage of fruits and vegetables in their fresh form prolongs their usefulness and in some cases improves their quality. It also checks market glut, helps in orderly marketing, increases financial gain to both the producers and consumer and preserves quality of produce for much longer time. Horticultural produce like fruits, vegetables and cut flowers are living respiring tissues separated from the parent plant. Therefore, the aim of storage is to control various physiological and biochemical processes viz. respiration, transpiration and other metabolic activities to keep produce in maximum usable form. Hence pre-treatments viz. Curing, Pre-Cooling, Inhibition of sprouting and fungicide application plays an important role to prolong the storage life of horticultural produce.

7.2 IMPORTANCE AND METHODS OF PRE-COOLING

Pre-cooling is the process of rapid removal of field heat/respiratory heat usually practiced for fresh fruits, vegetables and cut flowers immediately after harvest, before shipment, before cold storage or before processing depending on the commodity. This is the first step of good temperature management. The primary advantages of pre-cooling are: (a) Inhibition of the growth of decay causing organisms, (b) restriction of the enzyme activities, (c) reduction of water loss, (d) reduction in rate of respiration and C_2H_4 liberation and (e) rapid wound healing. The production and action of ethylene from harvested fruits, vegetables and flowers are temperature dependent. Harvested produce kept at 25^0 C with 30% RH shows a tendency of 36 times more water loss as compared to that stored at 0^0C with 90% RH. Hence pre-cooling serves as an essential practice in any successful cool chain management of horticultural produce. The two most important factors in pre-cooling are temperature and time, i.e. fruit or vegetable must be cooled in the shortest possible time. Product cooling follows a logarithmic function, with initial rapid cooling followed by a slower rate. Since it is difficult to remove all the field heat, pre-cooling to $7/8^{th}$ of the recommended storage temperature is advisable. The product can then be placed in storage where the remaining $1/8^{th}$ of the heat can be gradually removed with less energy cost. If several products are being handled, then a system must be selected that is compatible to all of them. Highly perishable products, which have a high respiratory rate, e.g., asparagus, broccoli, spinach and sweet corn, need fast cooling and require high refrigeration capacity and fast pre-cooling methods.

In order to predict the end point of pre-cooling, it is essential to know the "half-cooling time". Half-cooling time is the time required to reduce the temperature difference between commodities and the coolant by one-half. This is independent of the initial temperature of the commodity.

The speed of cooling depends upon the following factors: (i) Accessibility of product to the refrigerating medium. (ii) Difference in temperature between the product and refrigerating medium. (iii) Velocity of refrigerating medium and (iv) Type of cooling medium. The shape, density, and surface area/volume ratio of the fruit or vegetable and the type of container are important in determining the appropriate type of cooling medium, i.e. air, water or ice.

Some products do not tolerate exposure to water. In general, the greater the amount of packaging the slower the cooling rate. If the packaging is exposed to water, packaging in paper-based material is not recommended unless it is waxed.

There are basically five methods of pre-cooling used for horticultural commodities. These are (i) Room/air cooling, (ii) Water/hydro cooling, (iii) Forced air-cooling, (iv) Vacuum cooling, and (v) Package icing.

7.2.1 Room/Air Cooling

In room / air-cooling heat transfer takes place by means of conduction. Produce is placed in an insulated room equipped with refrigeration units. This method can be used in most commodities, but it is slow compared with other options. Containers should be stacked in such a way in the room so that cold air can freely move around them, with adequate space between stacks. The cost of room / air-cooling is a relatively low.

7.2.2 Hydrocooling

By hydrocooling, the product is cooled by immersing in cold water or by showering cold water on it. Heat transfer in hydrocooling takes place by both conduction and convection mechanism. It is faster than air-cooling and does not dehydrate the product. It can be used if the product is not damaged by exposure to water. The critical factors for effective hydrocooling are water sanitation and use of water-tolerant packaging that makes it more expensive. Hydrocooling has the advantage over other pre-cooling methods in a sense that it helps to clean the produce thereby reducing the primary inoculum load. The water is normally cooled by mechanical refrigeration but if this is not available an alternate source of cold water could be clean one source of water.

7.2.3 Forced-Air/Pressure Cooling

This method is a modification of room cooling in which pre-cooling is achieved by "pulling" cold air through the stacked product (Figure 7.1). In a properly designed forced-air system, the evaporator coils in the refrigeration system have more surface area than conventional coils, allowing for more rapid heat removal. Although the cooling rate depends on the air temperature and the rate of airflow, this method is usually 75-90% faster than room cooling. Fans should be equipped with a thermostat that automatically shuts them off as soon as the desired product temperature is reached. If mechanical refrigeration is not available, passing it through a water soaked pad that will remove heat can cool the air by evaporative cooling. Since evaporative cooling will cool the air to only 1-2°C above the wet bulb temperature of the air, it is most appropriate in dry climates and for chilling-sensitive products. Another alternative to mechanical refrigeration is to pre-cool the produce only at night when the air is colder. The main disadvantage of forced air-cooling system is desiccation of the produce due to very high velocity of air. To reduce this effect the cold air is humidified using appropriate air handlers.

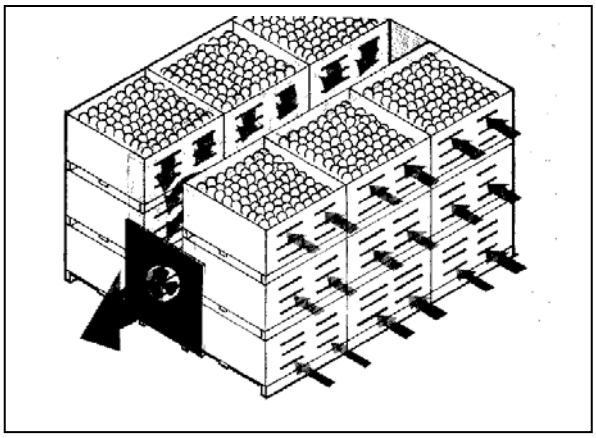

Figure 7.1: Technique of forced air cooling

7.2.4 Vacuum Cooling

This is the most rapid and energy efficient form of pre-cooling. Here the cooling is achieved by the latent heat of vaporization of water. Packaged product is placed inside an airtight chamber and the air is evacuated, which lowers the pressure and the boiling point of water. At a reduced pressure of 4.6 mm Hg, water on the surface of the product rapidly evaporates, which removes the field heat. Although this method can cool product in less than 30 minutes, it is only efficient on products with a high surface area/volume ratio. Crops having a relatively thick waxy cuticle e.g. tomatoes, grapes etc. are not suitable for vacuum cooling. Vacuum coolers are in limited use because they are expensive to purchase and operate and can only be used on a limited range of products.

7.2.5 Package-Icing

It is commonly applied to boxes of produce by placing a layer of crushed ice directly on top of the crop. The ice melts and the cold water runs down through the produce and is cooled. The main use of top icing is for road transport and it can be applied shortly after harvest to begin pre-cooling as soon as possible. By this method product is cooled faster than forced-air but the product must tolerate contact with water and ice. Although the easiest method is to add flaked ice on the top of the container, greater contact with the product can be achieved by injecting slurry of water and ice into the package. Care must be taken to ensure complete distribution in the package. Containers must be water-tolerant with holes for water drainage.

7.2.6 Alternate Methods of Pre-cooling

Several alternate methods of pre-cooling can be practiced in order to achieve the partial goal of pre-cooling in places where procurement and installation of expensive pre-cooling equipment are difficult. Some of the examples of the system could be (i) Radiant cooling by use of solar collector during night, (ii) High altitude cooling by utilizing naturally cool surrounding (about 10 c fall in temperature is recorded in every 1000m higher altitude.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark √ or ×.

   i) By pre-cooling the heat is removed from the produce at very slow rate.

   ii) Rapid removal of field heat is called pre-cooling.

   iii) One of the primary advantages of pre-cooling is inhibition of the growth of decay causing organisms.

   iv) Relative humidity of the cooling medium plays a great role in pre-cooling.

2. What are the various methods of pre-cooling of fruits and vegetables? What is half-cooling time?

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7.3 ROLE AND METHODS OF DRYING AND CURING

One of the most important methods of reducing post-harvest losses in many root crops such as yam and sweet potato and also for onions, is the use of surface drying and curing processes. Curing is a natural wound healing process in which harvested root and tuber crop replace and strengthen damaged areas by forming a corky layer which protects against water loss and infection by decay organisms. In contrast, the curing of onions, and garlic is mainly a drying process where excess moisture is removed from the outer skin and neck of the onion. At the same time, by exposing the onion to higher temperatures, the colour of the skin gets darkened and natural fungicidal compounds accumulate in the skin. Both processes together ensure the formation of protecting layer which greatly reduces water loss and serves as a physical and chemical barrier to infection.

Let us examine the mechanism involved in curing:

In most of the root and tuber crops suberization is the key process of curing. “Suberin” – a group of fatty acids imparts initial protection to water loss and infection to the harvested produce. The next important mechanism is the formation of periderm which is located below the suberized cells and formed by layer of meristematic cells. This is also called ‘cork cambium’ since it produces new cells that seals off the damaged areas. In the curing process deposition of suberin (suberization) in the parenchymatous cells (periderm) takes place simultaneously. The speed of suberization depends on: temperature, relative humidity and use of chemical sprout suppressant. Few cases showing the relation of temperature and humidity to the period of suberization are given below:

Factor	Effect
Curing Temperature $\geq$ 21°C	I day for suberization
Curing Temperature = 15°C	2 days for suberization
Curing Temperature = 10°C	5-8 days for suberization
Curing Temperature = 2.5°C	> 8 days for suberization
High R.H.	Better suberization
Low R.H.	Poor suberization
Use of chemical sprout suppressant	Inhibit suberization

The term curing is also sometimes used for citrus fruits. Generally, lemons are cured at 56º to 58º F (13.33–14.4º C) and 85-90% relative humidity. Green fruits may be held for 4 months or more, while the peel becomes yellow and thinner, the pulp juicier (6-80%) and the proportion of soluble solids higher (7-24%).

7.4 EFFECTS OF SPROUTING AND ITS INHIBITION

Roots, tubers and bulb crops have one common feature i.e. inflated storage organs. Containing a substantial amount of carbohydrate, protein and vitamins and minerals. Like many other fruits and vegetables, they remain active after harvest and carry out all the vital physiological and metabolic processes until its death. The high respiration rate of these crops after harvest not only brings about the compositional changes but also builds up temperature around it which in turn creates favourable conditions for the growth of microorganisms already present on these commodity. Although, these crops are not considered to be highly perishable, the severe problem of sprouting and rooting in storage limits their successful marketing.

Now, let us analyze the typical case of onion and potato. Commodities like onion and potato have buds that enter a dormant state at maturity. In this dormant stage, the plant can survive periods unfavourable to plant growth. This coincides with the appropriate stage of harvesting of these produce for orderly marketing for several months by storing them under appropriate conditions. The duration of post harvest dormancy in potato is commonly known as 'rest period'. The rest period is influenced by pre-harvest factors, maturity and variety. This is not dependent on temperature of the storage chamber in which the commodities are stored. Once the rest period ends, the sprouting begins and this is dependent on temperature of the storage environment. Sprouting of potato occurs rarely below 4°C, but storage at this temperature results in conversion of starch to sugars making the potatoes sweet. The sweetening of potato is not desirable from the point of view of processing or fresh marketing. Presence of sugars in potato adversely affect the quality of potato chips. Moreover, the consumers do not prefer the potatoes that are sweet in taste for even culinary purposes. Again, if the potatoes are stored at temperature above 4°C sprout growth will begin after 2-3 months storage. Sprouts are the new growths and comprise of highly active tissues. Therefore, sprouted potatoes quickly loose moisture, gets shrivelled and become prone to several microbial infection. Thus sprouting results in a huge post harvest losses. Apart from physical loss due to sprouting, the quality of sprouted potatoes became poor due to high respiratory utilization of substrates. Hence the control of sprouting becomes a first step in successful marketing of potato after harvest.

We will explain you the various methods of inhibition of sprouting. They are two common practices can suppress the sprouting. i.e. Use of chemical sprout suppressant either applied in the field i.e. pre-harvest application or after the harvest of the produce i.e. post harvest application and ii) Use of ionizing radiation. Maleic Hydrazide (MH-40), Nonylalcohol, 3-chloroisopropyl – N – phenylcarbamate (CIPC), Isopropyl phenylcarbamate (IPPC), methyl napthaleneacetic acid (MENA) and 2,3,4,6 tetrachloronitrobenzene (TCNB) are commonly used as sprout inhibitors. However, legal restrictions on usage of these chemical and their residual toxicity limit their use based on the legislation prevailing in a particular country. Out of these, MH is predominantly used as pre-harvest spray to control the sprouting of onion during storage.

As onions mature, tops begin to fall and dry. Sprout inhibitors are applied when onions are intended for long term storage. They are applied when tops are about 50% down, and there are 5 to 8 green leaves per bulb to absorb and translocate the sprout inhibitor. These are not applied when temperatures exceed 26-29°C to avoid crystallization on leaf surfaces. Use of a spray adjuvant is suggested. Avoid early sprays before maturity to reduce spongy onions. Maleic hydrazide (Royal MH-30) @ 0.9 Kg ai/Acre is most commonly used. Apply in sufficient water to insure adequate coverage. Most of the other chemicals are normally used as post harvest application. One should remember the fact that CIPC is one of the very stong sprout inhibitor used as post harvest application for long term storage of potato. It is applied as dust, water dip, vapour or thermofogging formulation. A normal dosage of 50 ml per one metric ton of potato is normally recommended. Potatoes become safe for consumption after about 30 days after treatment with CIPC depending on the temperature of storage. The most important advantage of CIPC treatment is the economy in saving electrical energy in cold storage since the potatoes could be safely stored at higher temperature of 10^{o}C without any sprouting or quality deterioration. Since CIPC interferes with the periderm formation, we must take care of its application only after proper curing. So far we have learnt about the chemical sprout suppressant.

Now let us learn about the use of ionizing radiation treatment to control sprouting in onion and potato. Under the present situation, use of gama irradiation @ 0.02- 0.15 kGY has been widely accepted by many countries for successful sprout inhibition of onion and potato without affecting the other quality attributes. However, the major limitation for use of irradiation is the high cost of specialized equipment, training and further more the consumer acceptability due to the fear of induced radioactivity and formation of harmful radiolysis products in irradiated produce. The report of world health organization (WHO, 1981) clearly concluded that irradiation to any food commodity to an overall average dose of 10 kGY had no toxicological hazards.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the main causes of spoilage of root, bulb and tuber crops?

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2. Explain how sprouting affects the quality of potato.

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3. What are the various methods of inhibition of sprouting of potato?

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4. Why irradiation treatments are not commercially used in India for checking sprouting of potato and onion during storage?

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7.5 WAXING AND SURFACE COATING

Fruits and vegetables have a natural waxy layer on the outer surface which gets partly removed during the washing process. An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency in the following objectives:

- Replacement of natural wax
- To reduce the water loss during shipment and storage
- To give a cosmetic appeal
- To cover up the minute injuries caused during post-harvest handling
- To use as a carrier of fungicide/inhibitor for better shelf life and
- To protect against decay organisms.

Sugarcane wax, carnuaba wax, shellac and various resins are common types of waxes used for-the preparation of wax-emulsion. Recently, sucrose polyester waxes are gaining popularity due to their water solubility and biodegradibility. Waxes are generally applied by foaming, spraying, dipping brushing and foaming. Foaming is a very satisfactory method since it leaves a very thin coating.

Apart from the above mentioned objectives use of surface coating and waxing creates a modified atmospheric condition between the cuticle and the coating material which reduces the physiological and metabolic activities in certain fruits. Some of the common surface coating materials used are: Semperfresh, Sta-Fresh, Citrashine, Waxol, etc.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark √ or ×.

   i) Fruits and vegetables have a natural waxy layer on the outer surface which gets partly removed during the washing process.

   ii) An extra discontinuous layer of wax is applied to reduce the water loss during shipment and storage and to give a cosmetic appeal to the consumer.

   iii) Commonly used candles are normally used for waxing of fruits.

2. Write six important objectives of waxing or surface coating of fruits and vegetables.

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7.6 POST HARVEST DISEASE MANAGEMENT AND FUNGICIDE APPLICATION

Different types of micro-organisms can cause spoilage in storage houses. However, bacteria and fungi are the most common. Bacteria are generally propagated by direct contact between perishable goods or with contaminated surfaces, or else with the water used during treatment before or after storage**.** Some of these bacteria can be pathogenic for human as well, for e.g. as *Listeria monocytogenes.* Vegetables are mostly spoiled by bacteria due to their high pH (4.5-7.0) whereas many fruits particularly the acidic fruits (pH < 4.5) inhibits the growth of bacteria but encourage fungal spoilage. A relative humidity less than 94 to 95 % is considered low enough for growth of bacteria. Majority of the soft rots causing bacteria have their optimum temperature for growth around 30°C. The following are the major bacterial species that infect the fruits and vegetables.

Sl. No.	**Commodity**	**Disease**	**Causal organism**
1.	Potato	Soft rot	*Erwinia cartovora* *Bacillus subtilis* *Clostridium sp*
2.	Onion	Rot	*Pseudomonas capacia*
3.	Cabbage, Lettuce	Rot	*Pseudomonas cicorii*
4.	Cauliflower, cabbage, tomato, bean, radish	Bacterial rot	*Xanthomonas spp*
5.	Mango, plum, cherry, peach	Bacterial rot	*Xanthomonas campestris*
6.	Pineapple, papaya, Guava	Bacterial rot	*Ewrinia spp*
7.	Apples and pear	Bacterial rot	*Pseudomonas spp*

Bacteria like Erwinia and Xanthomonas are mainly disseminated by leafhoppers.

Control of bacterial diseases: Chlorine compounds added to water as chorine gas or as hypochlorite solution could be used to kill bacteria rapidly. In commercial practice, 2 per cent Na-hypochlorite or 50 to 100 mg of chlorine or 1-1.5 g/litre chlorine dioxide are frequently used to control the bacteria. Low temperature storage is considered to be the best method for controlling the bacterial diseases.

Several fungal rots are considered to be of major importance causing severe post harvest losses to fruits and vegetables. The fungus forms acervulli from which single celled conidia arise. Acervulus is a clamp or cushion of conidia bearing on hyphae called conidiophore. The conidium on germination produces aspersorium, which helps in adhering of conidia to the skin. When the hyphae from the germinating conidia penetrate the surface of the fruits (unripe) these cause rotting. Hyphae that arise from aspersoria when the fruits start ripening can colonise the tissue and cause rot. This dormancy of aspersoria has been attributed to phytoalexin production or non-availability of nutrients in unripe fruits. This process of existence of fungal organism in the dormant form called latent or quiescent infection. Some of the examples of quiescent infections are mentioned below.

Sl.No.	Commodity	Causal organism
1.	Apple	*Gloeosporium perennans,* *Diplodia perniciosa,* *Nectria galligena*
2.	Citrus	*Colletotrichum gloeosporoides*
3.	Mango	*Colletotrichum gloeosporoides*
4.	Strawberry	*Botrytis cinerea*

In quiescent infections the development of fungus is stopped at the stage of aspersoriaor colonization.

Control of Quiescent infection in fruits:

i) Strict sanitation in pack house to reduce conidial rot

ii) Avoidance of injury

iii) Post harvest dips with systemic fungicides

a) Benlate @ 100 ppm
b) Benomyl @ 100-400 ppm
c) Thiabendazole @ 200 ppm

iv) Pre-cooling or cool chain management

The other fungal diseases include:

Finger rot of banana: this is caused by Botryodiplodia theobromae. The infection starts from the tip of the finger. The infected fruits soon become soft and brown. An aqueous dip in Thiabendazole @ 200-500 ppm for few seconds can control the disease.

The next important disease of banana is the crown rot caused by several organisms viz, *Cremonium spp, Botryodiplodia theobromae, Ceratocystis paradoxa, Colletotrichum musae, Fusarium pallidoroseum, Verticillium theobromae* etc. Treating with any of the systemic fungicides mentioned above could do successful control of this disease.

Dark brown spots with concentric rings on ripe banana may be due to Monilial disease caused by *Monilia fructigena or M. lexa*. Benomyl dip @ 0.2% or Thiabendazole @1200-2400 ppm dip could successfully control the disease.

Two major diseases of mango observed during post harvest stage are: I) anthracnose: caused by Glomerella cingulata (conidial stage *Colletotrichum gloeosporoides*). The symptoms appear on ripe fruits as black spots or streaks. Hot benomyl dip @0.1% at 52°C could successfully control the disease. The stem end rot of mango is associated with Botryodiplodia theobromae and or Aspergillus niger. Typical lesion of black to brown spots extending the stem is the major symptom of the disease. Thiabendazole @ 0.1% is the best control measure of this disease. Among the other pathogen Penicillium expansum is responsible for causing diseases to many fruits and vegetables e.g. apples, citrus etc.

Three major fungal organisms are mostly associated with post harvest diseases of vegetables. These are: (i) Fusarium spp causing rots in tinda, bean, cowpea, chilli, tomato, cauliflower, potato, cucumber, pointed gourd and pumpkin. (ii) Geotrichum diseases caused by Geotrichum candidum in tomato, pointed gourd, watermelon and muskmelon. As a thumb rule, the foods containing lactic acid are attacked by this fungus and (iii) Pithium diseases caused by Pithium spp. that attack okra and cucurbits. The following are the time temperature combinations for control of the fungal organisms:

Organism	**Temperature (°C)**	**Time/duration**
Botryodiplodia. Gloeosporium, Colletotrichum, Rhizopus	43-49 (Papaya)	20
Colletotrichum, Diplodia, Aspergillus, Bortyodiolodia, Rhizopus	47-55 (Mango)	10-20
Monilia, Rhizopus	49-84 (peaches)	1.5-3.5
Alternaria, Geotrichum	48-57 (Tomatoes)	5-10

The development of mould on walls or ceilings of the storage chamber may indicate insufficient insulation or a perforated or poorly installed vapour seal. Many of these organisms feed on perishable goods and organic matter. In the absence of nutrient sources, they can survive on other materials, such as wood and plastic. When they attack organic matter, bacteria and fungi can give off foul odours (ethylene and other volatile substances) that can change the taste or accelerate the maturation of stored fruit and vegetables. Although it is difficult to completely eliminate these micro-organisms, preventive measures and an appropriate clean-up plan can control their proliferation and greatly reduce the infection rate of perishable goods in storage houses. Micro-organisms, which are present in the storage house, also on fruit and vegetables, can be eliminated with an appropriate clean-up plan. The presence of any residue of plant material in the storage chamber can allow bacteria and fungus spores to survive between two storage periods. For a clean-up plan to be effective, it must follow certain steps in a specific order. These steps are cleaning, disinfecting, rinsing and drying. The techniques and products used to carry out each step must be adapted to treatment systems and storage facilities, whose main components.

Floors, walls, ceiling, doors and structural beams; refrigeration systems electrical fixtures; water and air pipes and channels and their components (drains, grill); wooden and plastic containers reused for storage of fruit and vegetables; pallets used to handle containers; machinery used in the storage house; waste containers.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark √ or ×.

   i) Fruits are mainly spoiled by bacteria whereas the vegetables are spoiled be fungi.

   ii) Soft rot of potato during storage is caused by *Pseudomonas spp.*

   iii) Anthracnose and stem end rot are the two major post harvest diseases of mango.

2. Write five important steps in controlling the quiescent infection in fruit crops.

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7.7 CONTROL OF RIPENING

Ripening is a dramatic event in the life of a fruit. It transforms a physiologically mature but inedible plant organ into a visually attractive taste and smell sensation. Ripening marks the completion of development of a fruit and the commencement of senescence, and it is normally an **irreversible** event. Ripening is the result of a complex changes, many of these probably occurring independently of one another. The changes that may occur during the ripening of freshly fruit are: Seed maturation, Colour changes, abscission (detachment from parent plant), Changes in respiratory and ethylene evolution rates, alteration in tissue/cell permeability, softening, changes in organic acids, Protein changes, production of flavour volatiles and development of wax on the skin.

On the basis of the respiratory pattern and ripening behaviour fruits are classified into two classes viz. **climacteric fruits** and **non-climacteric fruits**. As a thumb rule, the fruits which are harvested at optimum maturity and undergo ripening after harvest are grouped under Climacteric fruits; whereas another group of fruits that ripen on the tree itself and does not undergo much change after harvest or undergo further ripening are grouped under non-climacteric fruits. You observe the rise in respiration during ripening of the climacteric fruits but you don't find such trend in non-climacteric fruits. Some of the examples of both the groups of fruits are mentioned below:

Climacteric fruits are:

Apple, Apricot, Avocado, Banana, Blueberry, Fig, Kiwi fruit, Mango, Papaya, Passion fruit, Peach, Pear, Persimon, Plum, Muskmelon, Watermelon and tomato.

While Non-climacteric fruits are:

Cherry, Cucumber, Grapes, Lemon, Pineapple, Mandarins, Strawberry etc.

Climacteric and non-climacteric fruits may be further differentiated by their response to applied ethylene and by their pattern of ethylene production during ripening. It has been clearly established that all fruit produces minute qualities of ethylene during development. However, on ripening, climacteric fruits produce much larger amounts of ethylene than non-climacteric ones. Ethylene, applied at a concentration as low as 0.1–1.0 micro litres per litre for one day, is normally sufficient to hasten full ripening of climacteric fruits. However, the magnitude of climacteric is relatively independent of the concentration of applied ethylene. In contrast, applied ethylene merely increases the respiration of non-climacteric fruits, the magnitude of the increase being dependent on the concentration of ethylene. There are two different systems of introduction of ethylene in the ripening room. These are:

a) ***Shot system:*** Accurately measured quantity of ethylene is introduced into the ripening room at regular intervals using a gauge which registers the discharge of ethylene in cft/min. thorough ventilation is essential.

b) ***Trickle system:*** In this system the ethylene is introduced into the room continuously, rather than intermittently, as done in the shot system.

There are three major sources of obtaining ethylene for use in the ripening room:

i) Ethylene generators: In this a liquid (probably ethanol) produces ethylene when heated in the presence of a catalyst. This is used widely for supplying ethylene in the ripening room.

ii) Ethephon: It is commercially available as Ethrel or CEPA. To release l cft of C_2H_4 requires about 7 fluid ounces of active ingredient of ethrel. The solution of ethrel should be alkaline in order to release ethylene from ethrel. The ratio of Caustic soda: ethrel is approximately 3g: 20ml for effective release of ethylene.

iii) Ripe gas: This is compressed ethylene gas in mixed with CO_2 available in compressed cylinders. The normal concentration of ethylene in the ripe gas is 6% and CO_2 is used to make it non-inflammable.

Temperature and RH management of the storage rooms are the major factors responsible for control of ripening of fruits. The commodity should be stored at appropriate temperature and RH condition for extending its green life. These stored commodities can be ripened artificially by proper combination of temperature, RH and ethylene concentration in the ripening room. Besides temperature and RH management use of Controlled Atmosphere or Modified Atmosphere packaging or storage are proved to be successful in delaying the ripening of many fruits and vegetables and thereby extending the green life for orderly marketing practices.

The ideal condition for ripening by using ethylene in some important fruits and vegetables are mentioned below:

Fruit	Temperature (°C)	Ethylene Treatment (ppm)	Time (hours)
Avocado	18-21	10	24-72
Banana	15-21	10	24
Cantaloupe	18-21	Nil	
Honeydew melon	1821	10	24
Kiwi fruit	18-21	10	24
Mango	29-31	10	24
Papaya	21-27	Nil	
Pear	15-18	10	24
Pershimon	18-21	10	24
Tomato	13-22	10	Continuous

Ethylene is a colourless gaseous hydrocarbon with a faint sweetish smell having molecular weight 28.05; its boiling point at 760mmHg is −103.7°C. The flammable limits ranges from any composition between 3.10 to 32.00 %. It is a plant growth substance and a key to ripening of fruits and Vegetables. Its production is increased during leaf fall, flower senescence and fruit ripening. In addition, stress factors such as wounding, flooding, chilling, disease, high temperatures and drought seem to induce ethylene biosynthesis.

Threshold limit for ethylene action in various fruits varies from the type of commodity, but in most cases it ranges between 0.1−1.0 ppm. The duration of exposure may vary from 12 h to 72 h for initiation of ripening but full ripening may take several days. The effectiveness of ethylene in achieving proper and more uniform ripening depends on three important factors viz. (i) stage of maturity, (ii) temperature and RH in the ripening room, and (iii) concentration and duration of exposure to ethylene. In general, the ripening of fruits occur at 18-25^{0}C, 90-95% RH with 10-100 ppm ethylene and 24-72 h exposure depending on the commodity. Ethylene can be applied through ethylene generator using ethanol or by use of ethrel/ ethephon (2-chloroethyl phosphonic acid). One must remember the fact that ripening of fruits can be initiated by many other hydrocarbons viz. acetylene, propylene etc. But the efficacy of ethylene is considered to be 100 times more than acetylene. Calcium carbide was used for ripening fruits in India as a commercial practice. However, due to its deleterious effects on human health, it has been banned in India for use in ripening.

While storing fruits and vegetables care should be taken in such a way that the actively ethylene producing commodities should not be stored along with other fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life and specific symptoms of injury. Some examples of ethylene effects include: (i) Russet spotting of lettuce along the midrib of the leaves, (ii) loss of green colour in snap beans, (iii) increased toughness in turnips and asparagus spears, (iv) bitterness in carrots and parsnips, (v) yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower, (vi) accelerated softening of cucumbers, acorn and summer squash, (vii) softening and development of off-flavour in watermelons,

(viii) browning and discoloration in eggplant pulp and seed, (ix) discoloration and off-flavour in sweet potatoes, (x) sprouting of potatoes, (xi) increased ripening and softening of mature green tomatoes and (xii) shattering of raspberries and blackberries.

7.7.1 Biological Effects of Ethylene

Some of the very important biological effects of ethylene observed in plant tissues are mentioned below:

- **Respiration –** Ethylene increases the rate of respiration in both climacteric and non-climacteric fruits
- **Ripening** – The change in fruit physiology from maturation to ripening is initiated when cellular quantities of ethylene reach a threshold level
- **Flavour** – Ethylene exposure results in development of bitter taste in carrot and beetroot
- **Toxicity** – Pea pods exposed to 0.2 to 20 ppm ethylene developed *pisatin* (a phenolic phytoalexin), which is anti-fungal compound.
- **Colour** – Ethylene exposure cause rapid breakdown of chlorophyll, increase in carotenoid and lycopene content, so colour of petals of cut flowers can be affected by ethylene.
- **Disease –** High decay was observed in presence of ethylene in celery, brinjal, cabbage, and strawberries. Ethylene stimulated spore germination of fungi, which cause rotting.
- **Sprouting –** Ethylene has an opposite effect on dormancy and stimulates the activity of other growth regulators such as gibberellins.
- **Growth –** Ethylene can stimulate the growth of harvested crops which lead to undesirable effects e.g. loss of compactness foe to increase in inter node growth in Brussels sprout.
- **Texture –** Sweet potato and asparagus develop hard texture due to increase in fiber production. In orange and pineapple softening is hastened with ethylene levels of 1.0 ppm in the store.
- **Abscission –** Fruit stalk abscission increases in the presence of ethylene.
- **Floral senescence –** Hastening of senescence of cut flowers takes place when exposed to ethylene. Sleepiness in carnation is due to presence of ethylene causing the buds failure to open. Petal abscission and blueing of rose is also due to presence of ethylene.

Besides all these deleterious effects ethylene is highly beneficial and recommended for artificial ripening and degreening of fruits without posing any health hazard. Ethylene exposed fruits show more ascorbic acid content than unexposed fruit. Hence for the purpose of extending the storage life (green life) the removal of ethylene from the storage atmosphere plays a critical role for orderly marketing. However application of ethylene finds a good place on removal from store and during marketing.

Ethylene from the storage chamber can be removed by the following means: (i) elimination of source i.e. IC-engines, (ii) ventilation (iii) use of chemical scrubbing system e.g. $KMnO_4$ impregnated vermiculite / celite blocks (purafil), ozone, brominated or activated charcoal (iv) use of bacterial system e.g. *Mycobacterium* (v) hyobaric storage (vi) controlled atmosphere storage and (vii) by use of specific antiethylene compounds e.g. Silver nitrate. (Hydroxy quinolene citrate)HQC, HQS (H Hydroxy quinolene sulfate), Rhizotoxin and its analogues.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Fill in the blanks with appropriate word (s).

   i) On the basis of the respiratory pattern and ripening behaviour fruits are classified into two classes viz.____________ fruits and _______________ fruits.

   ii) Ripening marks the completion of fruit ________________ and the commencement of ____________and it is normally an _____________ event.

2. What are the different methods of artificial ripening of fruits? Explain in detail.

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3. Mention the different methods of removal of ethylene from the storage room

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7.8 LET US SUM UP

We should clearly remember that the fruits, vegetables and flowers after harvest remain alive and undergo high rate of physiological and metabolic activities i.e. increased rate of respiration, transpiration. Hence pre-treatments viz. Curing, Pre-Cooling, Inhibition of sprouting and fungicide application play a very crucial role to prolong the storage life of horticultural produce.

Pre-cooling is the process of rapid removal of field heat/respiratory heat, usually practiced for fresh fruits, vegetables and cut flowers immediately after harvest, before shipment, before storage or before processing depending on the commodity. This is the first step of good temperature management.

Curing is a natural wound healing process in which harvested root and tuber crop replace and strengthen damaged areas by forming a corky layer which protects against water loss and infection by decay organisms. In contrast, the curing of onions, and garlic is mainly a drying process where excess moisture is removed from the outer skin and neck of the onion. Sprouting results in a huge post harvest losses. Apart from physical loss due to sprouting, the quality of sprouted potatoes became poor due to high respiratory utilization of substrates. Hence the control of sprouting becomes a first step in successful marketing of potato after harvest

Vegetables are mostly spoiled by bacteria due to their high pH (4.5-7.0) whereas many fruits particularly the acidic fruits (pH < 4.5) inhibits the growth of bacteria but encourage fungal spoilage. A relative humidity less than 94 to 95% is considered low enough for growth of bacteria. Majority of the soft rots causing bacteria have their optimum temperature for growth around 30°C.

Ripening marks the completion of development of a fruit and the commencement of senescence, and it is normally an **irreversible** event. Temperature and RH management of the storage rooms are the major factors responsible for control of ripening of fruits.

Fruits and vegetables have a natural waxy layer on the outer surface which gets partly removed during the washing process. An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency in the following objectives: Replacement of natural wax; to reduce the water loss during shipment and storage, to give a cosmetic appeal to the consumer, to cover up the minute injuries caused during post-harvest handling, to use as a carrier of fungicide/inhibitor for better shelf life and to protect against decay organisms.

7.9 KEY WORDS

Curing : Curing is a natural wound healing process in which harvested root and tuber crop replace and strengthen damaged areas by forming a corky layer which protects against water loss and infection by decay organisms.

Pre-cooling : Pre-cooling is the process of rapid removal of field heat/respiratory heat usually practiced for fresh fruits, vegetables and cut flowers immediately after harvest, before shipment, before storage or before processing depending on the commodity.

Sprouting : Commodities like onion and potato have buds that enter a dormant state at maturity. The duration of post harvest dormancy in potato is commonly known as 'rest period'. Once the rest period ends, the sprouting begins. This process of breaking the dormancy is known as sprouting.

Latent infection : The process of existence of fungal organism in the dormant form called latent or quiescent infection.

Climacteric fruits : As a thumb rule the fruits which are harvested at optimum maturity and undergo ripening after harvest are grouped under Climacteric fruits.

Non-climacteric fruits: Group of fruits that ripen on the tree itself and does not undergo much change after harvest or undergo further ripening are grouped under non-climacteric fruits.

Ripening : Ripening is a dramatic event in the life of a fruit. It transforms a physiologically mature but inedible plant organ into a visually attractive taste and smell sensation.

Waxing/surface coating : An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency in order to replace natural wax lost during washing, reduce the water loss, give a cosmetic appeal, cover up the minute injuries, use as a carrier of fungicide and protect against decay organisms.

7.10 ANSWERS TO CHECK YOUR PROGRESS EXCERCISES

Check Your Progress Exercise 1

1. i) × ii) √ iii) √ iv) √
2. See sec 7.2. Your answer should include hydro cooling, room cooling, forced air cooling, package icing, vacuum cooling, alternate cooling. Definition of half-cooling time.

Check Your Progress Exercise 2

1. Your answer should include sprouting, rooting, rotting; See sec. 7.4.
2. See sec 7.4, Your answer should include increase in sweetness, loss in marketability, shrivelling, increased respiratory rate and aggravate rotting
3. See Sec. 7.4, your answer should include i) Use of chemical sprout suppressant as pre-harvest application or post harvest application and ii) Use of gama irradiation @ 0.02- 0.15 kGY. Maleic Hydrazide (MH-40) 3-chloroisopropyl–N–phenylcarbamate (CIPC), Isopropyl phenylcarbamate (IPPC), methyl napthaleneacetic acid (MENA) and 2,3,4,6 tetrachloronitrobenzene (TCNB).
4. See Sec. 7.4 , your answer should include high cost of specialized equipment, training , consumer acceptability due to the fear of induced radioactivity and formation of harmful radiolysis products in irradiated produce.

Check Your Progress Exercise 3

1. i) √ ii) √ iii) ×

2. See Sec. 7.5.

Check Your Progress Exercise 4

1. i) × ii) × iii) √

2. See Sec. 7.5. Your answer should include: sanitation of pack house, avoidance of injury, post harvest dips with systemic fungicides, pre-cooling or cool chain management.

Check Your Progress Exercise 5

1. i) Climacteric, Non-climacteric; ii) development , senescence

2. See Sec. 7.6, your answer should include use of ethrel, ethylene gas and calcium carbide, different methods of application of ethylene, temperature effect etc.

3. See Sec. 7.5, your answer should include (i) elimination of source i.e. IC-engines, (ii) ventilation (iii) use of chemical scrubbing system e.g. $KMnO_4$ impregnated vermiculite/celite blocks (purafil), ozone, brominated or activated charcoal (iv) use of bacterial system e.g. *Mycobacterium* (v) hyobaric storage (vi) controlled atmosphere storage and (vii) by use of specific antiethylene compounds

7.11 SOME USEFUL BOOKS

1. Burton, W.G. (1982) Post-harvest physiology of food crops. London and New York: Longman. 339 pp.

2. Dennis, C. (1983) Post-harvest pathology of fruits and vegetables. London: Academic Press. 264 pp.

3. Pantastico, Er. B. (ed.) (1975) Post-harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. Westport, CT: A VI Publ. Co. 560 pp.

4. Wills, R.H.H., Lee, T.H., Graham, De., McGlasson, W.B. and Hall, E.G. (1981) Post-harvest: An introduction to the physiology and handling of fruit and vegetables. Westport, CT: A VI Publ. Co. 163 pp.

UNIT 8 FACTORS AFFECTING STORAGE LIFE

Structure

8.0 OBJECTIVES

After going through this unit, you should be able to:

- know why low temperature is helpful in increasing storage life;
- tell the role of relative humidity in the maintenance of product quality;
- differentiate between climacteric and non-climacteric fruits; and
- explain the effect of low O_2 and high CO_2 concentration on fruits.

8.1 INTRODUCTION

Storage of fruits and vegetables is one of the most important aspects of post harvest management. It is estimated that about 30 percent of fruits and vegetables produced annually is lost in India due to inadequate post harvest management. Reduction in post harvest losses could increase the availability of fruits and vegetables without increasing production. One of the reasons for the post harvest losses of fruits and vegetables is lack of proper storage facilities. Refrigerated cool store is considered to be the best method for storing fruits and vegetables. But this method is not only highly energy intensive but also involves huge capital investment. The Expert, Consultation on Food Loss Prevention in perishable crops held at FAO, Rome in May 1980 recommended that the use of proper temperature management includes simple and low cost cooling system and the use of evaporative cooling for storage of fruits and vegetables.

Storage of fresh fruits and vegetables prolongs their usefulness and in some cases improves their quality: it also checks market glut, provides wide selections of fruits and vegetables throughout the year, helps in orderly marketing, increases financial gain to the producers, and preserves the quality of the commodities. The principal aim of storage is to control the rate of transpiration, respiration and disease infection and to preserve the commodity in its most usable form for consumers.

Storage life may be prolonged by proper control of post-harvest diseases, regulation of the atmosphere, chemical treatments, irradiation and refrigeration. To date, refrigeration is the only known economical method for long term storage of fresh fruits and vegetables; all the other methods of regulating ripening and deterioration are at best only supplemental to low temperature. In fact, other quality maintaining methods will not work satisfactorily without refrigeration. In a hot tropical climate, CA storage, waxing and use of polyethylene bags are not advisable if not combined with refrigeration, as deterioration would be fast due to rapid build up of heat and CO_2.

Storage life of the fresh horticultural product is affected by many factors; most important of them are temperature and relative humidity. Fresh fruits and vegetables are living tissues and continue to respire after harvest. Storage temperature is the most important environmental factor affecting the senescence of fruits and vegetables because it regulates the rate of all associated physiological and biochemical processes. Many physiological processes are affected by temperature after harvest. Changes in quantity and quality affect horticultural crops between harvest and consumption. While some of the changes are desirable, most are not. Senescence is the final stage in the development of plant organs during which a number of changes take place that lead to breakdown and death of the plant cells, and storage life of produce is terminated.

8.2 PRINCIPLES OF STORAGE

8.2.1 Control of Undesirable Plant Processes

Since all fruits and vegetables are living tissues, the tendency after harvest is a continuation of all life processes. The aim of storage is to minimize the rate at which these processes take place. Thus, proper and adequate storage conditions must be supplied to the product; otherwise, the following undesirable plant processes may occur.

Sprouting

This can be a serious cause of deterioration, especially in onions, ginger, garlic sweet potatoes and potatoes. Sprouting is related to dormancy and rest. Dormancy is a condition of quiescence due to some internal or external factors. Rest is a phenomenon in which sprouting does not occur in spite of a favourable environment. Of the crops mentioned above, only sweet potatoes have no state of rest.

Elongation of Existing Structures

This process may be exemplified by products such as asparagus, carrot, beet and kohlrabi.

Rooting

Rooting may be initiated by a condition of elevated humidities, which may result in rapid decay, shrivelling and exhaustion of food reserves, especially in roots and tubers.

Seed Germination

During storage, seed germination within mature fruits is favoured. This process is observed in tomatoes, papaya and pod bearing vegetables. In most cases this may not be objectionable, but is detrimental in canning of whole tomatoes.

Greening

Exposure of potatoes to light during storage may produce green tissues. These portions contain solanine, which has some toxic properties. Thus, during storage, light should be minimized.

Toughening

Green beans and sweet corn may toughen when storage is unduly prolonged due to the development of spongy tissues.

Tropic Response

Response to gravity and light may cause bending of tissues. Products of uneven shapes are difficult to package. Appearance of the product, when offered for sale is also affected.

8.2.2 Control of Transpiration

Of the environmental factors, temperature, RH and vapour pressure difference (VPD) are important in transpiration. Low temperature, high RH and small VPD are necessary to minimize shrinkage of the product. A 5% loss in weight of a fruit is enough to produce shrivelling which makes it unattractive for sale. In using high RH during storage, care must be taken not to allow the development of surface moulds and other decay organisms due to condensation of moisture on the surface of the products. It can be controlled by proper packaging, use of protective coatings and by keeping the refrigerant as close as possible to the desired air temperature.

8.2.3 Control of Respiration

The basic principle in cold storage is the retarding effect of low temperature on respiration. Respiration is a breakdown process and means to minimize this process should be provided. Controlled atmosphere storage has proved to be a good commercial supplement to refrigeration. Its feasibility in the tropics should be explored.

Ventilation is indirectly related to respiration. Usually, the heat generated by respiration accumulates at the centre of the storeroom, and if provisions are not made for its exit, the rate of respiration of the stored products will be increased. It will be noted that since respiration and storage life are intimately related, whatever factors affect one will also influence the other.

8.3 TYPES OF STORAGE OPERATION

The enormous increase of fruit and vegetable production, owing to larger acreage and high yielding varieties, requires sufficient storage space. Accordingly, storage operations have been developed into a skilful job with a wide range of variations depending on the existing facilities and the nature, kind and quantity of products.

Storage operations may be either temporary, short term or long term. Temporary storage operation is needed for highly perishable products which require immediate marketing. It may be installed with or without refrigeration. This is extremely important for road side stands, market gardens, railway stations, shipping yards and retail stores. Mid term storage operation is aimed at checking the market glut without much deterioration in quality. This may extend from 1 to 6 wk, depending on the need. Mango, banana, papaya, cabbage, brinjal, tomatoes, cauliflower and beans are transferred to short term storage rooms when their quality is still good, and held there until a reasonable market price is attained. They are constantly inspected. Crops like apples, oranges, pomelos, pears, squash, potatoes, colocasia, sweet potatoes, carrots, onions, garlics and pumpkins are stored for a longer period of time. Long term storage operation is principally influenced by economic factors. The products are stored during their peak periods of production and marketed continuously during the rest of the year when producers and dealers can obtain reasonably high prices.

Storage operation may be classified as either natural or artificial. Artificial storage operation may be divided further into 4 types: (a) mechanical or structural, (b) controlled atmosphere, (c) chemical and (d) radiation. Natural storage operation keeps the products in situ without any artificial treatment. The aim is to let the fruit or vegetable mature and ripen on the plant for as long as possible. Harvesting is therefore delayed. Artificial storage operation, on the other hand, attempts to provide all possible artificial storage conditions to prolong the usability of the product.

8.3.1 Natural Storage

In India, particularly in West Bengal, vegetables like potato, yam, sweet potato, garlic and ginger are kept in situ for several months after they attain maturity. These are removed keeping in view the market rate. Staggering the harvest is easy and economical because it does not involve any extra expenditure and fabrication for storing. The vegetables are generally, removed before the rainy season to prevent rotting and sprouting.

8.3.2 Artificial Storage

Vegetables are stored in pits and trenches by mounting soil on the surface. Pits are used for storing beets, potatoes, carrots, turnips, cabbage, parsnips, sweet potatoes etc. Except for cabbage and parsnips, the vegetables are first covered with hay, straw or litter and then with soil to protect the surface from water leakage and freezing.

The small trenches should be dug at right angles to each other to facilitate ventilation. Wooden planks or boards are often placed above. The soil, about 4 to 5 in thick is filled with hay or straw and the products are piled inside the trench. A similar cover of straw or hay is placed above the commodity and plastered with mud. Several small trenches are better than one or two large ones. When a trench is opened all the stored products should be removed at a time. The location of the trenches should be on well drained high land. There should be no surface drain near the trench.

Untopped beets are stored underground, 12 to 16 inches deep in regions of mild winter. At the start of severe cold, 2 adjacent rows are placed in covered with soil. In this way, beets, which are neither too young nor too mature, can be kept for 5 to 6 months. In British Columbia, a cover of 4 to 5 inches is enough, but in the southern states, from 8 to 10 in is usually necessary.

Underground field storage offers the advantage of being convenient for the grower, as it can be done anywhere at anytime. Space is not restricted. It is most suitable for short term storage operations. However, many disadvantages render this type of storage unfavourable. It is expensive in terms of labour charges from digging the pit to removal of the product. Weather and soil conditions influence the operation. Heavy losses may occur since climatic conditions cannot be controlled. Deterioration can be faster for vegetables not removed before cold and wet weather.

8.3.3 Low Cost Storage Structures

Low cost storage system has a great significance in our country since other advanced storage systems work ought to be extremely expensive. Most of the low cost storage structures are built by taking the advantage of natural cooling.

i) Clamps

The clamps are commonly used for potatoes, turnips, beet etc. and vary in design. An area of land at the side of the field which is not prone to water logging is selected. The width can be any convenient size but normally it ranges between 3'-7'5" and it can be any suitable length. These dimensions are marked out and the vegetables piled on the ground. Occasionally straw is put on the ground before keeping the vegetables. The height of the pile should be about 1/3 of its width. The pile is covered with whole wheat or rice straw to about 6-8" thick, when compressed. In colder climates, more straw and soil may be added.

ii) Cellar

These are underground or partly underground structures usually below a house. They are used for years as storage for fruits and vegetables. The cellar temperature is approximately equal to the average annual air temperature. Cool under ground spaces work well for storing already cooled produce but not for removing field heat.

iii) Night time cooling

In some parts of our country there are significant differences between night and day temperatures allowing night time ventilation to be a good source of cool temperature.

iv) High altitude cooling

High altitude can be a source of cold. As a thumb rule air temperature decreases by 10°C for every 1 km increase in altitude.

v) Zero energy cool chambers

It is based on the principle of evaporative cooling. Evaporative cooling is not only one of the simplest and cheapest methods but also does not involve any conventional energy source or power to operate. Evaporative cooling is widely used for comfort cooling of living and working spaces in hot, dry climates and has considerable potential for pre-cooling and even storage of fruits and vegetables in such climates.

The basic principles are evaporation of water produces considerable cooling effect and the faster the evaporation, the greater the cooling. Evaporative cooling occurs when air that is not already saturated with water vapour is blown across any wet surface. Thus an evaporative cooler consists of a wet porous bed through which air is drawn, cooled and humidified by evaporation of water. Theoretically the lowest temperature that can be reached by the evaporation of water is the wet bulb temperature.

8.3.4 Ventilated Storage

a) **Above ground warehouse:** This is a common type of structure built above the surface of the ground and extensively used by rural farmers in the Indian peninsula. A dwelling house may be used for this purpose. The nature and type of construction depend on the area and nature of the product to be stored. In cold regions, greater insulation is needed, whereas in warm areas proper ventilation is essential. A storage structure for sweet potatoes differs from that for onions, leafy vegetables, crucifers or mangoes.

   This structure has the following advantages over the other types: (a) special construction is not needed, since a dwelling house will satisfy the conditions provided it is provided with necessary fittings suited for the particular type of fruits or vegetables; (b) products are easily handled during storage and removal; (c) grading, storing and packing of fruits and vegetables are facilitated.

b) **Controlled atmosphere storage:** Artificial atmospheres have been maintained in storage rooms in several ways. The respiration by the fruits increases the concentration of CO_2 and decreases the O_2 in the room. Proper levels are maintained by CO_2 absorbers, usually NaOH. Water is also used for absorbing CO_2 from CA storage when the concentration becomes too high. This method was less expensive and less noxious than with NaOH.

8.3.5 Refrigerated Storage

Although costly, the advantages of refrigerated or low temperature storage are well known. The following general principles should be considered during planning the refrigerated warehouse.

Site selection: The site of a storage plant should be selected bearing in mind its accessibility to highways, production areas, shipping points and distribution centres. Availability of fuel, telephone systems, electricity, water and sewer should also be considered. The site should be levelled so that costs of excavations and steep driveways are minimized.

Utilization of space and equipment: Mechanical product handling and newer methods of construction tend to give single story design greater capacity per rupee of investment than multi story refrigerated warehouse. In a one-story structure, high ceilings are provided; thus ducts, refrigeration units, pipes, sprinklers and other overhead obstructions should be placed so that they do not interfere with the use of vertical space. Small columns on wide centres permit palletized storage with comparatively little lost space.

Insulation requirement: A good insulating material must have low thermal conductivity, permanence, ease of application, reasonable cost and moisture-resisting qualities. The best insulating medium possible is two silver-coated surfaces separated by a perfect vacuum. This is used in small units (e.g. Thermos bottles) but is impractical in a larger scale. Still air is the second best insulator, but in practice this is not realized because of convection currents carrying heat. Other insulating materials include granulated cork, charcoal, cellular ebonite, glass fiber, kapok, cane fiber boards, silicate cotton (slag wool), cellular plastics, balsa wood, saw dust, rice husk and coconut fibers. However, they are not as efficient as slab cork. Usually they absorb moisture readily, causing decreased resistance to heat flow and structural deterioration.

To protect the insulator against entry of water vapour, a vapour barrier is needed. Since this travels inward, from the warmer to the colder side, the vapour seal should be placed on the outer surface of the insulator. Plastic film, metal foil, rigid metal sheets or hot mastics will provide adequate vapour seals.

Insulation is not usually placed on floors if the ground water level is more than 12 ft below the floor surface. Dry ground is a fairly effective insulator. Insulation thickness varies with the average and extreme temperatures of the location and temperature of the room. For cold storage of fruits and vegetables in the tropics, 4 to 5 in of cork insulator are sufficient.

Ventilation: Storage rooms should be provided with a forced air distribution system, which will allow uniform airflow throughout the pile of commodities. Air should circulate from the centre of the room outward to the walls, down through and between the rows of commodity and back up through the centre of the room. This is made possible by providing ducts or blowers and proper stacking of containers to permit airflow in a pre determined direction.

Refrigeration doors: Doors should permit easy access in and out of the room and at the same time minimizes undue loss of refrigeration. Bumper doors (or air doors) are convenient because they are self-closing and can easily be opened by dumping them with a fork lift truck. A hinge-insulated door opening should have at least 12 inch clearance on both sides of a pallet. The recent tendency is to use 10 feet as the standard height to accommodate all types of stacking lift trucks.

8.4 FACTORS AFFECTING STORAGE LIFE

8.4.1 Temperature

All fresh commodities contain water in their tissues and therefore are subjected to desiccation, which makes them susceptible for deterioration by other factors, such as microbial infection. Further elevated temperature influences the deterioration rate of harvested commodities. For each increment of 10°C, the rate of deterioration increases by two-to-three fold. Exposure to undesirable temperature results in many physiological disorders. Temperature also influences the effect of ethylene, reduced O_2 and elevated CO_2. Temperature can also influence the incidence or severity of pathogens.

8.4.2 Relative Humidity

In addition to temperature, relative humidity (RH) is the other factor which influences water loss from the product. It is important to maintain the RH level to optimum as lower RH may cause desiccation of the product, and higher RH may lead to condensation of water on fruit surface which may invite a host of problems.

8.4.3 Atmospheric Composition

Reduction of O_2 and elevation of CO_2 can either delay or accelerate the deterioration of fresh horticultural produce. The extent of these effects depends on commodity, cultivar, physiological age, O_2 and CO_2 level, temperature and duration of holding.

8.4.4 Physiological State-Respiration Rate and Ethylene Evolution

Respiration rate and ethylene evolution are major factors determining the storage life of harvested commodity. Respiration is the process by which stored complex materials are broken into simple products and energy is released. While respiration is essential to maintain the state of living of the produce, it causes deterioration due to losses in food reserves, food value, flavour, and dry weight. Further, a good amount of energy is released during respiration. The rate of deterioration of harvested produce is generally proportional to their respiration rate.

Ethylene is the natural ripening and senescence hormone, which is physiologically active at very low concentration (0.1 ppm). While all the plants produce ethylene, its production varies greatly. Generally ethylene production rate increases with maturity at harvest, physical injury, disease incidence, increased temperature and water stress. It can be controlled by storing at low temperatures and reduced O_2 and elevated CO_2 atmosphere.

8.4.5 Initial Infection and Physical Condition of Produce

The produce should be in good condition before storage. Harvesting should be done in a manner that it doesn't cause impact, bruising or injury to the product. Bruising may stimulate respiration and enhance ethylene production that accelerates ripening and associated changes. The bruised or cut sites may invite microbial infection, which ultimately reduces the life of the product.

8.4.6 Pre-harvest Factors

The prevailing climatic conditions and cultural practices determine the quality of the produce. The incidence of infection at the time of harvest will determine the storage life of a commodity. A sizable proportion of stored produce is spoiled by these infections.

Storage life partly reflects the cultural and environmental conditions to which the produce is exposed before harvesting. The environmental factors include temperature, RH, light, soil texture, wind, elevation, and rain fall; whereas cultural factors are mineral nutrition, soil management, pruning, thinning, chemical spray, rootstocks, planting density and irrigation.

I) Climatic influences

Temperature: The metabolism and composition of the fruit are affected by temperature. Tomatoes grown at high night temperature have higher respiration rates than those, which grow at lower night temperature and ultimately have lower shelf life.

Light: The duration, intensity and quality of light affect the quality of fruit and vegetable at harvest and have influence on the shelf life. In tomatoes leaf shading of fruits produces a deep red colour, and the fruits exposed to the sun are lighter in weight with thinner rind. Such fruits are more susceptible to mechanical damage and have higher transpiration rate; and lower shelf life.

Water supply: Water supply to plant during growth also affects the storage life. Fruits and vegetables grown under water deficit condition may not develop properly and will have shorter shelf life. Similarly under water logged conditions may cause development of water soaked areas on commodity reducing the storage life.

Wind: Wind may damage the leaves of the vegetables or cause abrasions on fruit surface, which reduces their shelf life. High wind velocity may have a deleterious effect on plant growth.

II) Cultural practices

Several factors before harvest affect quality of horticultural crops after harvest. The quality of the seed or the plant material is an important factor that controls the fruit produced. Besides this genetic makeup of plant also determines the quality of the product. All cultural practices have direct effect on final quality of the produce.

Seeding or planting period: Many species are very sensitive to environmental conditions, so optimum quality of produce cannot be expected when crop is grown under adverse conditions.

Planting density: Planting density can affect both quality and quantity of produce. In high density planting competition among plants is increased which reduces light availability, and thus may decrease its quality. Low density planting leads to large sized fruits with good colour. But larger fruits are commonly more susceptible to physiological disorders.

Environmental conditions during growth: High temperature, light intensity, wind rain, hail, storm and snowfall are the environmental conditions that may influence the quality of the produce.

Irrigation: Irregular watering usually reduces fruit size, increases splitting and physiological disorders, and it reduces water content in fruit or plant.

Fertilization: Poor fertilization increases chances of physiological disorders due to deficiency of some minerals, or excess may lead to toxicity of some minerals. Nutrition of the plant is the most studied factor affecting the quality of harvested produce and its storage life. Many physiological disorders are the result of depleted nutrient status or nutrient toxicity in the soil. High level of nitrogen promotes stem end rind breakdown in citrus, and cracking in sweet potato, where as deficiency of nitrogen causes stunted growth. Deficiency of potassium leads to black spot in potatoes. Calcium deficiency causes reduction in firmness besides causing cavity spot in carrots. Besides the major nutrients, micronutrient deficiency also affects product storage life. Fruits of citrus become hard and grow to irregular shape and contain brown gummy discoloration in the albedo if grown in boron deficient soil.

Pruning: Pruning reduces the load in plants, and leads to good fruit development in the plant. Fruits from well pruned tree can be expected to have more storage life than unpruned tree due to proper growth and development.

Thinning: Thinning reduces the competition between fruit trees, and therefore promotes a good balance between the vegetative parts and fruit, which results in improvement of quality.

Disease and insect control measures: Incidences of pathogens and insects have negative effect on fruit quality. Poor management of plant protection programs has the potential of not only reducing yield, but quality also.

Hormone and growth regulators used during growing season: Many hormones and growth regulators are sprayed during growth season to improve the quality of fruit/vegetables.

Chemical sprays: Chemical sprays during pre-harvest are done for control of weeds, insects and pests, and control of nematodes. Timely and adequate concentrations of these sprays improve the quality of the produce.

Rootstock: The effect of genetic material on storage potential after harvest is well documented. Different cultivars of same fruit vary in their storage requirement and storage life.

Other cultural practices: Any factor that affects plant growth also influences the quality of harvested produce. Age of the tree also influences the size and quality of the fruit, as in orange the older trees have smaller fruits with thin rinds, but high TSS. Further interactions among different levels of climatic and cultural factors during growth may affect the fruit quality and its storage potential.

8.4.7 Harvesting and Handling Practices

These likewise influence storage behaviour and quality. Merely dropping the fruit to the ground from a height of only a few inches will cause an outburst of CO_2 production, which may not be immediately counteracted by low temperature storage. Bruises, punctures, scratches and other mechanical injuries can be expected to produce even greater damage. Hence, careful handling and prompt storage should be practiced.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How temperature affects the respiration rate of the product?

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2. What is the effect of lowering oxygen content in maintaining quality of fresh produce?

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3. How relative humidity affects the quality of fresh produce?

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4. What is the effect of low temperature storage on fruit quality?

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5. What is the relationship between respiration and deterioration of quality of fresh horticultural product?

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6. Differentiate between climacteric and non-climacteric fruits.

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7. What is senescence?

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8. How bruising during harvesting affects the storage life of the horticultural commodity?

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8.5 LET US SUM UP

Being a live tissue, fruits and vegetables continue to perform metabolic activities even after harvesting, which is the major cause of their spoilage. Therefore proper storage after harvest is necessary to maintain the product quality after harvest. The product should be stored under optimum conditions of temperature to reduce its respiration and ethylene production, which leads to senescence. Maintaining proper humidity and alteration of product environment during storage also helps in extending the storage life of fresh produce.

8.6 KEY WORDS

Relative humidity	:	The relative amount of moisture in the atmosphere
Desiccation	:	Removal of water from the surface
Harvesting	:	Detaching the edible portion from the plant
Impact	:	To hit with force against a hard surface
Bruising	:	To injure the surface without breaking the skin, but causing Discoloration.
Microbial infection	:	Growth of microorganism on a product
Ethylene	:	A gas which stimulates ripening
Respiration	:	Process of inhaling oxygen and exhaling carbon-di-oxide

8.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:
   - Rate of chemical and biochemical reactions
   - Severity of pathogen infection
2. Your answers should include following points:
   - Temperature regulation
   - Ethylene removal
3. Your answers should include following points:
   - Desiccation
   - Pathogen infection
4. Your answers should include following points:
   - Reduced respiration
   - Reduced ethylene production

- Low pathogen incidence
- Enhanced shelf life

5. Your answers should include following points:

   - Loss of storage material
   - Ethylene production
   - Heat production

6. Your answers should include following points:

   - Respiration
   - Ethylene production

7. Your answers should include following points:

   - Death of tissues
   - Termination of metabolic activities

8. Your answers should include following points:

   - Enhanced ethylene production
   - Site for pathogen attack
   - Blackening of surface

8.8 SOME USEFUL BOOKS

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UNIT 9 STORAGE STRUCTURE

Structure

9.0 OBJECTIVES

After reading this unit, you should be able to:

- explain orderly marketing of fruits and vegetables thereby increase the period of availability;
- understand the role of temperature, humidity and atmospheric gases during storage;
- state different high-tech and low cost traditional storage techniques;
- demonstrate the principle of evaporative cooling and the role of Zero Energy Cool Chamber; and
- highlight the importance of refrigerated/cool stores for the benefit of the producers and consumers.

9.1 INTRODUCTION

Storage of fruits and vegetables is very much essential, because of their highly perishable nature. Their storage can be extended by various treatments applied to them after harvest. The most important of these is temperature management. Orderly marketing of these perishable commodities requires some storage facility in order to balance day to day fluctuation between product harvest and their sale.

Fruits and vegetables are grown in many parts of the country but not uniformly. During harvesting season, availability is abundant in one region but generally scarcity in other parts. The season lasts for few days to few weeks and this situation creates a glut in growing area and the growers do not get a remunerative price of their valuable produce. As a result, they encounter more spoilage and force to undertake distress selling at the instance of unscrupulous traders. Considerable difference exists in marketing of perishable fruits and vegetables and that of durable cereal grains. Consumers generally prefer to buy a small / requisite quantity of vegetables daily or once/twice a week because of their perishable nature. While in case of other items of food viz. cereals, pulses, vegetable oil, spices etc are normally procured once in a month as they are durable in nature primarily because they contain less moisture compared to fruits and vegetables. In order to extend marketing of these perishable commodities beyond the end of harvest season, proper storage of fruits and vegetables become essential.

A proper storage system reduces physiological activity of horticultural commodities by maintaining lowest safe temperature that will not cause chilling or freezing injury. It also reduces growth of spoilage causing microorganisms. With some commodities, the storage facility may also be used to apply special treatments like curing of tuber and other fruits and vegetables. For example potatoes and sweet potatoes are held at high temperature and high relative humidity for few hours/days to cure wounds sustained during harvest, drying of scaly leaves of onion and garlic, and degreening of oranges and lemons and application etherals for uniform ripening before marketing or shipment.

9.2 REFRIGERATED/COOL STORAGE

Fruits and vegetables if stored at low temperature remain fresh and nutritious for a longer time. Low temperature reduces physiological activity rate of the product like respiration, transpiration, ethylene production and other biochemical reactions responsible for rapid ripening and senescence. It also minimizes attack of pest and diseases and prevents product dryness with the help of humidifier in the storage room. Refrigerated storage is one such type of storage structure where temperature can be brought down with the help of mechanical refrigeration. This system doesn't produce cooling but removes heat from the storage that we feel is cooled. Refrigeration cycle in the compression system is by far the most popular and most widely used system of refrigeration. It consists of four important units namely compressor, condenser, cooling coil and expansion valves.

A good refrigerant changes into vapour phase upon heating and in liquid state upon cooling. The refrigerant (Fereon-12) or ammonia takes out the heat from the room and changes into vapour. The expansion valve controls the amount of refrigerant. The expanded gas is then compressed in compressor and thus the heat is removed from the compressed gas by means of running water or circulating cool air over the cooling coils containing the hot gas. The hot gas changes into liquid in condenser. Once the refrigerant is returned to the liquid state, it is again ready to be admitted through the expansion or the pressure-reducing device on to the evaporation. This cycle of actions in the compression system is repeated continuously so long as the compressor is in operation and with such a system accurate temperature control is possible. The ideal condition in the cool store is the lowest minimum temperature that does not cause chilling injuries to the produce.

Table 9.1: Recommended cool store temperature and relative humidity of some important fruits

Fruit	Temperature °c	Relative humidity%	Storage (days)
Apple	-0.1- +4	90-95	30-50
Banana	13-15	85-90	30-45
Grape	+1 -	90-95	60-90
Guava	5-10	90	14-21
Lemon	10-14	90	60-150
Lime	9-10	90	30-60
Litchi	1.5	90-95	21-35
Mango	13.3	85-90	15-25
Orange	4-6	85-90	45-80
Papaya	12.2	85-90	7-21
Pineapple	10-13	90	21-28
Sapota	12.2	85-90	14-21

Source: Hardenburg, R.E.; Watada, A.E. and Wang, C.Y. (1990)

Table 9.2: Recommended cool store temperature and relative humidity of some important vegetables

Fruit	Temperature °c	Relative humidity%	Storage (days)
Broccoli	0	95-100	10-14
Cabbage	0	98-100	21-42
Carrot	0	98-100	210-270
Cauliflower	0	95-98	21-27
Cucumber	10-13	95	10-14
Eggplant / Brinjal	8-12	90-95	7
Green peas	0	95-98	7-14
Melons	10-15	90	14-21
Okra	7-10	90-95	7-10
Onion	0	65-70	180-240
Potato	3-8	90-95	150-300
Tomato (Ripe)	8-10	90-95	4-7

Source: Hardenburg, R.E.; Watada, A.E. and Wang, C.Y. (1990)

9.3 CONTROL/MODIFIED ATMOSPHERE STORAGE

It is an advance technology for storage of fruits and vegetables. In these systems, storage environment is different than the normal. Controlled atmosphere (CA) storage utilizes the correct amount of gas combination during storage. In CA, oxygen is reduced from 21% to 2-5% and CO_2 is increased from 0.03 to 1-5%. These results slow down of physiological activity of fruits and vegetables such as rate of respiration, ethylene production and other bio-chemical reactions. The reduced rate of these activities actually decreases the ripening and senescence process considerably. Construction and running of CA storage needs special attention such as it should be gas tight, mechanical refrigeration should be attached to maintain a temperature of 30-32 ^{0}F. Nitrogen and CO_2 gas are introduced into the storage and excess CO_2 must be removed by dry hydrated lime because high CO_2 is not tolerated by many commodities. No doubt, CA storage has many advantages but few harmful effects have also been recorded. For example, Initiation of black heart in potatoes, brown stains on lettuce, irregular ripening of banana, pear, tomato and development of off-flavour at very low O_2 concentration.

Modified atmosphere inside the package develops due to the respiration of fruits and vegetables. Inside the package O_2 decreases and CO_2 increases with the uptake of O_2 and release of CO_2. In MA storage, a very low degree of control gas concentration is possible. However, a desired gas combination can also be obtained by placing absorbers and adsorbers of O_2, CO_2 and ethylene. The MA and CA differ mainly in degree of control of gas concentration. Advances in the design and manufacturing of polymeric films with wide range of gas permeability increased the efficiency of MA storage.

9.4 ICE BANK COOLER

In efficient cooling system cooled air passes over the stored fruits and vegetables at a very high velocity as a result desiccation of the crop takes place. In order to avoid this, various methods of humidifying the cooling air have been developed. A recent development in refrigeration is the Ice Bank Cooling system with positive ventilation. The system positively directs ice cold air through the boxes or crates containing fresh fruits and vegetables. In this way quicker cooling is possible and large amount of heat can be removed in a relatively short period of time. In this system, a bank of ice is built up with the help of a small refrigeration plant. The ice is accumulated on extended surface plate, which are suspended in a tank of water. The water surrounding the ice is pumped to the top of a cooling tower and falls through the tower passing over the extended surface, giving a large surface area of heat exchange. The air leaving the tower maintains high relative humidity. Once initial cooling is complete the store maintains a temperature of 0.5 - 0.8^{o}C and relative humidity of 98 per cent. In view of the continuous humid cool air circulated through the stored commodities this system of storage is found very useful for storage of fresh horticultural produce. This will be preceding step for cool storage of fruits and vegetables.

9.5 HYPOBARIC STORAGE

Fruits and vegetables can be stored under less than atmospheric pressure. This technology is called hypobaric storage. Fruits were held at about 0.2 to 0.5 atmospheric pressure at 59 to 75°F and humidified air was passed through the chamber in order to maintain humidity and to remove ethylene and other volatile compounds given off by the fruits and vegetables. There is reduction of ethylene in the fruit tissues and O_2 in the chamber. As a result, products respiration and ethylene production decreases which results increased shelf - life. Many volatile compounds evolved by the produce and from other sources may accumulate in the storage atmosphere. Ethylene is the most important volatile compound accumulated in the storage room. Its accumulation above certain level may reduce storage life. Therefore, its removal becomes necessary. Hypobaric storage is a form of controlled atmosphere storage in which the produce is stored in partial vacuum. In hypobaric storage system, the commodity is placed in a vacuum tight and refrigerated container and air is evacuated by a vacuum pump to the desired low pressure. This is a very expensive method and used in case of high value commodities.

9.6 LOW COST STORAGE

Low cost storage structures are the best alternative for rural areas and in all such places where electric facility is not available. It is easy to install and run by unskilled people. These low cost storage systems have a great significance in our country since other advanced storage techniques work out to be extremely expensive. Most of the low cost storage structures are build by taking the advantage of natural cooling and all of them are not only environment friendly but also energy saving.

Clamps

These have been used from time immemorial as a traditional method of storage. The clamps vary in design and commonly used for potatoes, turnips, beet etc. An area of land at the side of the field that is not susceptive to water logging is selected. The width can be any convenient one but normally it ranges between 3' – 7. 5' and it can be any suitable length. These dimensions are marked out and the vegetables piled on the ground. Occasionally straw is put on the ground before the vegetables. The height of the pile should be about 1/3 of its width. The pile is covered with unbroken what or rice straw to about 6.8" thick, when fully compressed, laid upright from ground to ridge and capped at the top with bent over straws. About 2 weeks after the clamp is covered with a layer of soil, usually in the order of 6-8" thick when compressed. In colder climates more straw and soil may be added.

Pits

Normally pits or trenches are dug at the edges of the field where the crop is grown. One should remember that the site of pits or trenches in the field should be at higher points particularly in high rainfall regions. These are lined with straw or any other organic matter before filling with the commodities to be stored and then covered with a layer of organic matter and then with a layer of soil. Sometimes wooden boards are placed on the surface before the soil is put on. Some times lack of ventilation may cause rotting problems. This can be avoided by providing ventilation hole at the top in such away that it allows only air to pass out but no rain to penetrate.

Cellar

These were underground or partly underground structures usually below a house. This location provides good insulation as a result they are protected from excessively low temperatures in cold climates. They were used for years as storage for fruits and vegetables. The crops are usually spread out thinly on shelves in order to ensure good air circulation. The doors of the cellars are generally kept open at night to ensure that the temperature in store remains low. It has often been observed that the cellar humidity remains low that may induce desiccation. In order to avoid such situation precaution is taken to keep the floor of the store wet. As a general rule, the cellar temperature is approximately equal to the average annual air temperature. Cool under ground spaces work well for storing already cooled produce but not for removing field heat.

Night time cooling

This is also called as air cooled storage system. This method actually should consist of an insulating room from all the sides with air inlet and out let for exchange of air. During night open these pores and allow the cool air to come inside. By putting an exhaust fan at out let will increase the efficiency of nighttime cooling. It will facilitate more sucking of cool air inside for faster air circulation and rapid cooling. During daytime both inlet and outlet are kept closed. The trapped cool air will keep the produce cool. The relative humidity can also be maintained by sprinkling water on the floor or by providing mechanical humidifier. Fruits and vegetables can be stored for few days to a few weeks depending on the out side temperature. In some parts of the world, there are significant differences between night and day temperatures allowing night time ventilation as an efficient system of storage of fruits and vegetables. In hilly areas also night temperature falls as high as 15 to 20°C. Low night temperature can be used to reduce field heat simply by harvesting the produce during early morning hours.

Well water

In some areas, well water can be an effective source of cold. The temperatures of the ground at depths greater than about 2m (5feet) below the surface is equal to the average annual temperature. Well water temperatures are usually very near to this.

Naturally formed ice

This is an old method of refrigeration and very useful for cold countries where water of lakes, ponds are frozen in winter season. The ice is harvested and stored in insulated houses and used for pre-cooling, storage and transportation of horticultural commodities. Before the development of mechanical refrigeration, refrigeration was provided by ice formed naturally in shallow ponds during winter. The ice was insulated from spring and summer heat with straw and transported to cities as needed. But the cost of transportation was found very high as compared to electrical cost for refrigeration. Generally one Kg of ice takes 325 Kilo Joules of energy for complete melting. The heat comes form the commodities and its immediate surroundings that results cooling. But this method requires a large quantity of ice and creates problem of disposal of melt water. However, cooling facilities in climates where winter ice making is feasible can store for summer use. In case of few fruits and vegetables, it is best suited for transportation along with ice.

High altitude cooling

High altitude can also be a source of cold. As a thumb rule, air temperature decreases by 10°C (18°F) every 1Km increase in altitude. It is not possible to bring this air down to ground level because it naturally heats up as it drops in altitude. However, in some cases it may be possible to store the commodity at high altitude in mountainous areas.

Underground storage

Cellars, abandoned mines, and other underground storage have been used for years for storage of fruits and vegetables. The temperature inside storage is approximately equal to the average annual air temperature. It should be noted that cool underground spaces work well for already cooled produce but not for removing field heat. The soil has a poor ability to transfer heat. Once the cold is depleted from an area it will not regenerate rapidly. Use of soil at the top for insulating the underground pit is important in order to avoid run-off and rain water to enter into the pit. A small tube is generally inserted inside the pit for gaseous exchange.

Ventilated storage/onion storage structure

The conventional storage structures used in India for onion are primarily made of bamboo or similar plant material with a thatch on top. All attempts are made to provide side and bottom ventilation, but unfortunately due to indiscriminate piling of onion heat pockets develop because of improper ventilation of onion stack. As a result of inadequate ventilation, spoilage is accelerated. Therefore, air movement is essential for onion storage. Considerable reduction of spoilage of onion could be achieved by modifying the existing storage structure and introducing pile ventilation with the help of perforated bamboo pipes. It was observed that storage of onion in perforated plastic crates stacked in a ventilated room/shed could reduce the storage losses due to spoilage to a considerable extent. The big size cool chamber can be used as an ideal onion storage structure if the water is withdrawn from the system.

9.7 EVAPORATIVE COOLING/PUSA ZERO ENERGY COOL CHAMBER

Evaporative cooling is Nature's very own method. The ancient Egyptians used a primitive form of evaporative cooling, dating back to about 2500 BC and so did the Mughals a few centuries ago. Evaporation of water produces a considerable cooling effect and the faster the evaporation the greater is the cooling. Evaporative cooling occurs when air, that is not already saturated with water vapour, is blown across any wet surface. Thus evaporative coolers consist of a wet porous bet through which air is drawn and is cooled and humidified by evaporation of water. Theoretically, the lowest temperature that can be reached by the evaporation of water is the wet bulb temperature. Evaporative cooling is widely used for comfort cooling of living and working spaces in hot, dry climates and it has a considerable potential for pre-cooling and even storage of fruits. The principles of evaporative cooling can be gainfully utilized for storage of fresh produce, particularly in rural India, as it can be constructed even in a remote village.

This is a low cost storage structure, based on the principle of evaporative cooling. The most important advantage of this low cost technology lies in the fact that it requires very minimal electricity or power to operate and all the construction material of cool chamber are available easily and cheaply. It can be installed by low skill persons as it does not require any specialised skill. Only the place / site should have a permanent source of water. The raw material required for the construction of cool chamber are bricks river bed sand, bamboo, khaskhas, rice straw (or any material of similar nature), gunny bags/cloths etc. Its construction is also very simple. First of all floor is made with a single layer of bricks and the side wall are made with a double layer of bricks leaving a cavity of approximately 7.6 cm space in between the two layers of bricks. This cavity is filled with river bed sand free from stones and other materials. The top cover is made with khaskhas or gunny bags in a bamboo frame structure. About 400 bricks are required to built a cool chamber for 1 quintal of fruits or vegetables. After construction, wall, floor sand and top cover should be wetted fully by water. Once the chamber is fully saturated with water, sprinkling of water once in the morning and once in the evening is enough to maintain the temperature and humidity. These cool chambers can reduce the temperature by 17-18°C during the peak summer months and maintain a very high humidity of about 95 per cent throughout the year even when the atmospheric relative humidity falls below 20 per cent. The improved system of watering by single drip in zero energy cool chamber was found to be efficient in maintaining slightly lower temperature compared to the conventional system. It also helped in saving considerable amount of water and labour. Few precautions should be taken to run this chamber successfully, that there should be a permanent source of water, it should be constructed under shade and the site should not be prone to water logging condition. Spray recommended insecticide/ fungicides before storage. The shelf life of fruits and vegetables could be increased from a few days to few weeks in these chambers.

Commercial size cool chamber

The low cost big size cool chamber has been designed and constructed with the double brick wall having cavity filled with riverbed sand. The bottom of the chamber is provided with four ducts that are submerged in wet sand. The floor of the chamber is made of wooden planks with provision of the entry of fresh air through the duct. An exhaust fan has been provided at the top for ventilation purpose. The trial with big size cool chamber showed that it could bring down the temperature by 8-10°C. The study revealed that the temperature could be brought down efficiently by judicious operation of the exhaust fan.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why do we need storage of fruits and vegetables?

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2. What are the different types of low cost storage systems other than Pusa Zero Energy Cool Chamber?

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3. Write the utility of Pusa Zero Energy Cool Chamber (PUSAZECC).

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4. What are the high-tech. storage systems?

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5. Write different components of refrigerated storage?

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6. How CA differs from MA storage?

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9.8 LET US SUM UP

Storage of fruits and vegetables is essential to extend the period of availability for orderly marketing, pricestablization, spoilage reduction and distribution to the places of scarcity. Many biotic and abiotic factors effects the storage life of fruits and vegetables after harvesting. In order to control these factors many, high-tech storage systems are developed such as refrigerated storage, Controlled/Modified atmosphere storage, Hypobaric storage etc. However, such high-tech storage are costly, requires power to operate and skilled persons which a small farmer can not afford. On the other hand, low cost storage systems are found very useful for on farm. Pusa Zero Energy Cool Chamber is one such low cost storage system. It requires very low or minimal electricity or power to operate nor any skilled person to operate, maintains low temperature and high humidity. Small and marginal farmers can adopt this low cost storage to store his daily harvesting instead of selling to middlemen at cheapest rate. In addition commercial size cool chamber can be constructed in a in village hat for storage purpose.

9.9 KEY WORDS

Evaporative cooling : Evaporative cooling occurs when air that is not saturated with water vapour is blown across any wet surface.

Zero energy cool chamber : Low cost storage structure for storage of horticultural perishable.

Relative humidity : Ratio of weight of water vapour present in the air and the weight of water vapour required to fully saturate the air, expressed in percentage.

Processing : Sterilizing process by the application of heat.

9.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - It regulates market price and facilitates orderly marketing of fruits and vegetables.
   - Increases availability of fruits and vegetables during off-season.
   - Extend the shelf-life of fruits and vegetables beyond the harvesting season.
   - Increases the marketing period of fruits and vegetables.
   - Beneficial to both the producers and the consumers.

2. Your answer should include the following points:

   - Underground storage such cellars, abandoned mines, caves etc.

- Cooling by naturally formed ice
- High altitude cooling
- Night time cooling
- Storage in clamps

3. Your answer should include the following points:

   - It does not require any electricity or power to operate.
   - All the construction material of cool chamber are available easily and cheaply.
   - Any person can install it at any place/site (with a permanent source of water).
   - It maintains high humidity and low temperature which is essential to preserve freshness and prevents desiccation of horticultural produce during storage.
   - It increases shelf-life of fruits and vegetables and preserve their nutritional quality.

4. Your answer should include the following points:

   - Refrigerated storage
   - Controlled atmosphere storage.
   - Modified atmosphere storage.
   - Hypobaric storage
   - Ice Bank cooler

5. Your answer should include the following points:

   - Expansion valve
   - Compressor
   - Condenser
   - Cooling coil
   - Refrigerant

6. Your answer should include the following points:

   - CA maintains required level of gases in the storage, which is not possible in MA.
   - In CA required amount of gases are maintained by injecting or removing but not in MA.
   - In MA respiration of fruits or vegetables modifies gases composition.
   - Packing of fruits and vegetables in a polyethylene pouch is an example of MA.
   - CA requires airtight room with refrigeration and gases controlling facility.

9.11 SOME USEFUL BOOKS

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5. Wills, R.B.H.; Lee, T.H.; Graham, D.; McGlasson, W.B. and Hall, E.G. (1989) Post-harvest: An introduction to the physiology and handling of Fruits and Vegetables, New York: Van Nostrand.

6. Zero Energy Cool Chamber, Research Bulletin No.43. Indian Council of Agricultural Research, New Delhi.

UNIT 10 MARKET AND MARKET MECHANIZATION

Structure

10.0 OBJECTIVES

After reading this unit, you should be able to understand:

- concept of markets;
- what role markets play in economic development?;
- various classifications of markets and marketing channels;
- various types of market functions that are performed in the marketing and role of market middlemen;
- marketing efficiency and how to measure marketing efficiency; and
- what is meant by market mechanization, its role and scope?

10.1 INTRODUCTION

In the traditional subsistent society, most of the people earned their livelihood from land and had little left for marketing. This marketable surplus was exchanged locally only. The distance between producers and consumers was less. Small quantities of commodities were transported as head loads to places of demand. There were limited varieties of commodities brought to market. The commodities were normally sold in raw form and seasonally only. Roads were not developed and time was not properly valued. All the marketing services were performed manually. However, slowly and slowly market centres developed where bulk of commodities started flowing in. The urbanization further helped in establishing big markets. However, with a larger proportion of commodities moving to urban markets and more proportions available for commercial markets, certain kinds of problems, characteristic to the stage of development, also became apparent.

With the stage of development, the income of the people increased the demand for better markets and better marketing services also increased. A wide range of variety of commodities also developed. Those producers who could meet the consumers' demands, gained. The part of gain was further invested for improving marketing facilities and services. Government also helped in establishing the modern markets.

However, there were many problems too. With the increase in population and further increase in income and urbanization, the demand for fast marketing services increased. The limited supply of increased marketing services could not keep the pace with demand. Thus the need for the mechanization of the markets was felt to meet the demand, promptly.

Transportation in the market itself became fast. Well developed countries today have mechanical grading, packing, stitching and loading and unloading of the commodities in the market places. The weighing machines immediately weighs the commodities accurately even to fractions. A similar mechanized system is needed to move manufactured inputs to farm from urban areas where they are produced.

10.2 CONCEPT AND DEFINITIONS

In any market oriented economy, the production is mainly for sale to the consumers. The direct sale of the producer to the consumer can bring higher price to him. But the search of consumers for direct sale is normally costly. The direct sale to consumers is not possible by every producer especially when producer faces shortage of labour and time. The market place serves a better outlet, in such situation, where more amounts can be sold with less labour and time. It is in this context that the formal markets with modern facilities, especially for agricultural produce are of paramount importance in agricultural countries like India.

Traditionally, a "market" was a physical place where buyers and sellers gathered to exchange goods. A market includes any area/place where the people assemble for sale and purchase of the commodities that satisfy their demand. Thus, it is an area in which the demand and supply forces operate.

Economists describe a market as a collection of buyers and sellers who transact over a particular product. But marketers view the sellers as constituting the industry and the buyers as constituting the market. Business people often use the term markets to cover various groupings of customers such as product markets (the shoe market); demographic markets (the youth market); and geographic markets (the Indian market).

The traditional boundary of the market in terms of place is now relaxed. We can distinguish between a marketplace and a market space. The marketplace is physical, as one goes shopping in a store; market space is digital, as when one goes shopping on the Internet. Many observers believe that an increasing amount of purchasing will shift from the marketplace. Today, each nation's economy and the global economy consist of complex interacting sets of markets linked through exchange processes.

Thus, the term market means not a particular market place in which things are bought and sold but the whole of any region in which buyers and sellers are in such a free intercourse with one another that the prices of the same good tend to equality, easily and quickly. Therefore, a market is defined in terms of existence of fundamental forces of supply and demand and is not necessarily confined to a place.

Some necessary conditions for a market to exist are:

- Reference of the commodity
- Existence of buyers as well as sellers
- Existence of business relationship between buyers and sellers.
- Medium of exchange.

Thus, market is an arena for organizing and facilitating business activities and for answering the economic questions: What to produce, how much to produce and how to distribute? The marketing on the other hand is performance of all business activities involved in flow of goods and services associated with inputs and output from initial point of production to ultimate consumers.

10.3 ROLE OF MARKETS

The markets provide most convenient outlet for producers and consumers. These provide livelihood to various people who perform different kinds of activities /functions. Since, the commodity prices are principal factors affecting the level of living of both producers and consumers in developing counties, it is often desirable to measure the returns to the farmers and also lower cost to consumers in order to raise their standard of living. Well organized/ regulated and managed market does not permit malpractices.

Free markets play a very important role in the development of a country by providing the right direction to the resources' use and fulfil the demand of all types of consumers and producers of variety of goods. They operate to make a variety of products to targeted consumers at various places in desired form and conditions and deliver to those who are willing to pay reasonably.

Well developed marketing system in rural areas will further add to increase the market for industrial goods. Thus, a good marketing system acts as a motivating force for development of a country. The market demand will signal the, production and the employment and profitability.

It is important to note that an efficient, viable marketing system can not be realized without institutions which provide financing , assume risk, aid exchange by impartially mediating set weight and measures, grades and standards and help to disseminate market facts.

10.4 TYPES OF MARKETS

Markets are of various types and can be divided on various bases. Some of the basis on which, agricultural markets can be classified are given below:

Classification of Markets:

10.4.1 On the Basis of Location

On the basis of the place or location or operation, markets are of the following types:

a) *Village markets:* A market which is located in a small village, where major transactions take place among the buyers and sellers of a village, is called a village market.

b) *Primary wholesale markets:* These markets are located in big towns near the centres of production of agricultural commodities. In these markets, a major part of the produce is brought for sale by the producers-farmers themselves. Transactions in these markets usually take place between the farmers and traders.

c) *Secondary wholesale markets:* These markets are located generally in district headquarters or important trade centres or near railway junctions. The major transactions of commodities take place between the village traders and wholesalers. The bulk of arrival in this market is from other markets.

d) *Terminal markets:* The terminal markets are those in which goods produced are finally either sold to the consumers/processors or assembled for export. Such markets are located either in cities or near sea ports.

e) *Seaboard markets:* These markets are located near seashore. These are mainly for exports/imports. Such markets are Mumbai, Kolkata and Chennai.

10.4.2 On the Basis of Area Covered

On the basis of the area from which buyers and sellers usually come for transactions, markets may be classified into the following four classes:

a) *Local or village markets:* This covers a village/local area. In this type of market the buying and selling activities are confined among the buyers and sellers drawn from the same village or nearby villages. The village markets exist mostly for perishable commodities in small lots, e.g., egg market, local milk market or vegetable market.

b) *Regional markets:* Regional market is one in which buyers and sellers for a commodity are drawn from a larger area than the local markets. Regional markets in India usually exist for food grains such as Moga market for wheat.

c) *National markets:* A market in which buyers and sellers are at the. National level. National markets are found for durable goods like spices, jute and tea.

d) *World market:* The buyers and sellers are drawn from the whole world. These are the biggest markets from the area point of view. These markets exist in the commodities which have a worldwide demand and/or supply, such as coffee, machinery, gold, silver, etc.

10.4.3 On the Basis of Time Span

The markets can be classified on the basis of the duration for which they work.

a) *Short-period markets:* The markets which are held only for a few hours are called short-period markets. The highly perishable commodity/ products assemble at a place near village or city to market the produce like fish, vegetables and in these markets, the prices of commodities are governed mainly by the extent of demand for, rather than by the supply of, the commodity.

   There are weekly markets in many places where all commodities including agricultural commodities are sold at a particular day in a week.

b) *Long-period markets:* These markets are held for a longer period than the short-period markets. The commodities traded in these markets are less perishable and can be stored for longer time. These are food grains and oi1seeds. The prices are governed both by the supply and demand forces.

c) *Secular markets:* These markets are of a permanent nature. The commodities traded in these markets are durable in nature and can be stored for many years. Examples are markets for machinery, manufactured goods.

10.4.4 On the Basis of Volume of Transactions

The markets on the basis of volume of transactions at a time can be divided into two.

a) *Wholesale markets:* A wholesale market is one in which commodities are bought and sold in large quantities or in bulk. The farm produce from far off places is normally sold to wholesaler here. However, transactions take place between traders also.

b) *Retail markets:* Transactions in these markets take place between retailers and final consumers. The retailer purchase in wholesale market and sell in small lots to the consumers as per their requirements. These markets are very near to the consumers.

10.4.5 On the Basis of Nature of Transactions

The markets can also be classified on the basis of nature of transaction. These markets are of two types

a) *Spot or cash markets:* A market in which goods are exchanged for money on the spot is called the spot or cash market.

b) *Forward markets:* A market in which the purchase and sale of a commodity takes place at time ‘t’ but the exchange of the commodity takes place on some specified date in future i.e., time t + 1. Sometimes even on the specified date in the future (t + 1), there may not be any exchange of the commodity. Instead, the difference in the purchase and sale prices are paid or taken.

10.4.6 On the Basis of Degree of Competition

The market can be classified on the basis of competition of exchange of commodity between buyers and sellers. On the basis of competition, markets may be classified into the following categories:

Perfect Markets: A perfect market is one in which the following conditions are satisfied:

i) Large number of buyers and sellers exist.

ii) All the buyers and sellers in the market have perfect knowledge of prices.

iii) Prices of homogeneous goods at any time are uniform over a geographical area, plus or minus the cost of getting supplies from surplus to deficit areas.

iv) The prices are uniform at any place over periods of time, plus or minus the cost of storage from one period to another.

v) The prices of different forms of a product are uniform, plus or minus the cost of converting the product from one form to another.

vi) There is free entry and exit of the buyers and sellers.

Imperfect Markets: The markets in which perfect competition conditions lack are characterized as imperfect markets. The following situations, each based on the degree of imperfection, are normally identified:

a) *Monopoly market:* Pure Monopoly is a market situation in which there is only one seller of a commodity. He exercises sole control over the quantity or price of the commodity. In this market, the price of a commodity is generally higher than in other markets. But when there is only one buyer of a product, the market is termed as a Monopsony market.

b) *Duopoly market:* A duopoly market is one which has only two sellers of a commodity. They mutually agree to charge a common price which is higher than the hypothetical price in a perfect market. The market situation in which there are only two buyers of a commodity is known as the duopsony market.

c) *Oligopoly market:* A market in which there are more than two but still a few sellers of a commodity is termed as an oligopoly market. A market having a few (more than two) buyers is known as oligopsony market.

d) Monopolistic competition: When a large number of sellers deal in heterogeneous or differentiated form of a commodity, the situation is called monopolistic competition. The difference is made conspicuous by different trade marks on the product. Different prices prevail for the same basic product. Examples of monopolistic competition faced by farmers may be drawn from the input markets. For example, they have to choose between various makes of insecticides, pump sets, fertilizers and equipment.

10.4.7 Classification of the Market on the Basis of Public Intervention

Based on the extent of public intervention, markets may be placed in anyone of the following two classes:

a) *Regulated markets:* Markets in which business is done in accordance with the rules and regulations framed by the statutory market organization. Standards, grades and charges in such markets are fixed.

b) *Unregulated markets:* There are no official rules, regulation and public controls. The market rules etc. are made by the private parties only, in these markets.

10.5 MARKETING FUNCTIONS

Each of marketing function is a major specialized activity performed in accomplishing the marketing process. The list of the marketing functions differs among the writers. However, we shall follow a fairly widely accepted classification of functions, as follows:

A. *Exchange functions:*

1. Buying (assembling)
2. Selling

B. *Physical functions:*

1. Storage
2. Transportation
3. Processing

C. *Facilitating functions:*

1. Standardization
2. Financing
3. Risk-bearing
4. Market intelligence

The ***exchange functions*** are the activities involved in the transfer of title to goods. They represent the point at which price is determined during marketing. These functions are never performed in our economy without a judgment of value, usually expressed at least partially as a price, being placed on the goods. Both the buying and selling functions have as their primary objective, the negotiation of favourable terms of exchange.

The ***buying*** *function* is largely, one of seeking out the sources of supply, assembling of products, and the activities associated with purchase. This function can be either the assembling of the raw products from the production areas or the assembling of finished products into the hands of other middlemen in order to meet the demands of the ultimate consumer.

The ***selling*** *function* includes most of the physical arrangements of display of goods. Advertising and other promotional devices to influence or create demands are also part of the selling function. The decision like proper unit of sale, the proper packages, the best marketing channel, the proper time and place to approach potential buyers can be included in the selling function.

The ***physical functions*** are those activities that involve handling, movement, and physical change of the actual commodity itself. They are involved in solving the problems of when, what, and where, in marketing process.

The *storage function* is primarily concerned with making goods available at the desired time. The owners of a product hold large quantities of raw materials until they are needed for further processing. It may be the holding of supplies of finished goods as the inventories of processor, wholesalers and retailers.

The *transportation function* is primarily concerned with making goods available at the proper place. Adequate performance of this function requires the weighing of alternatives of routes and modes of transportation as they affect transportation costs. It includes the activities involved in preparation for shipment, also.

The *processing* function is often excluded in the list of marketing functions because it is a form-changing activity. However, in the broad view of agricultural marketing this activity cannot be omitted. The processing function would include all those essential manufacturing activities that change the basic form of the product, such as converting fresh peas into canned or frozen peas, or wheat into flour and finally into bread.

The ***facilitating*** **f*****unctions*** are those that help in smooth performance of the exchange and physical functions. These activities are not directly involved in either the exchange of title or the physical handling of products. However, without them, the modern marketing system would not be possible. These functions serve as the grease that makes the wheels of the marketing machine go round.

The *standardization function* is the establishment and maintenance of uniform measurements. These may be measurements of both quality and quantity. This function simplifies buying and selling, because it makes the sale by sample and description, possible. It, therefore, is one of the activities that make possible mass selling. Effective standardization is basic to an efficient pricing process. A consumer directed system assumes that the consumer will make his wants known largely through price differentials. These differentials must then be passed back through the marketing channel so that marketing agencies and producers can know what is wanted. Well-defined units of quality and quantity of a commodity can fetch a better price. Standardization also simplifies grouping of similar lots of commodities at producing points. After their establishment, the use of standards must be policed. Such activities as quality control in processing plants and inspections to maintain the standards in the marketing channel can be considered part of this function. In addition, certain aspects of the packaging activity are a standardization procedure of units of sale as well as being part of the merchandising activity of the selling function.

The *financing function* is the advancing of money to carry out the various aspects of marketing. The capital is tied up between the time of the first sale of raw products and the sale of finished goods to the ultimate consumer. Someone must finance this holding of goods. The period may vary from 3 months for perishable and more than six months for semi perishable products. Financing may be from various lending agencies or owner's capital resources. In either instance, it is a necessary activity in modern marketing.

The *risk-bearing function* is the accepting the risk of loss in the marketing of a product. These risks are physical risks and market risks. The physical risks are those that occur from destruction or deterioration of the product itself by fire, accident, wind, earthquakes, cold, and heat. Market risks are those that occur because of the changes in value of a product as it is marketed. An unfavourable movement in prices might result in high inventory losses. A change in consumer taste might reduce the desirability of the product. A change in competitors marketing situation might result in a loss of customers. All these risks in varying degrees must be borne in the marketing of a product. Risk-bearing may take a more conventional form, such as the use of insurance companies in the case of physical risks or utilizes the future exchanges in the case of price risks. Or, as is often true, the entrepreneur himself may bear the risk without the aid of any of these specialized agencies. The function of risk-bearing is often confused with the function of finance. Their differences can be kept clear, however, if it is remembered that the need for financing arises because of the time lag between the purchase and sale of products, thus the need for risk-bearing arises because of the possibility of loss during the holding period (unlike the function of financing which is because of time lag between purchases and sales).

The *market intelligence function* involves collecting, interpreting, and disseminating the large variety of data necessary for the smooth operation of the marketing processes. Efficient marketing cannot operate in an information vacuum. An effective pricing mechanism depends on well-informed buyers and sellers. Successful decisions on how much to pay for commodities or what kind of pricing policy to use in the sale require a large amount of market knowledge. Adequate storage programs, an efficient transportation service, and an adequate standardization program, all depend to a considerable extent on good information. As with other functions, this function may be performed by those who specialize in its performance. On the other hand, everyone in the marketing process who buys and sells products, evaluates available market data and therefore tries to perform this function efficiently.

10.6 MARKETING CHANNELS

Marketing channels may be defined as alternative route of product flow from producer to consumers. Or, we may define marketing channels as the set of various agents/ firms/ individuals that take title or assist in transferring goods/services as it moves from producer to the final consumer.

The analysis of marketing channels is intended to provide a systematic knowledge of the flow of goods and services from their origin (producer) to their final destination (consumer). This knowledge is acquired by studying the "participants" in the process, i.e., those who perform physical marketing functions in order to obtain economic benefits. In carrying out these functions, marketing agents achieve both personal and social goals. They earn a (personal) financial reward by performing an activity desired by society. They add value to product and in doing so help satisfy customers' needs. The price the consumer pays for the goods (the physical commodity) and services (e.g., storage, transportation, bulk-bearing, grading) rendered, compensates the marketing agent for his efforts. This price also serves as a signal to all the actors in the marketing channel, i.e., producers, rural assemblers, transporters, wholesalers, and retailers etc.

Producers and consumers are part of all marketing channels. The number of intermediaries in between these two will indicate the length of channel. For example:

Zero level – producer → consumer

One level – producer → whole seller → consumer

Three level – producer → miller → whole seller → consumer

The following marketing channels for general food grains in India.

Some common marketing channels for wheat have been identified as follows:

a) Farmer to consumer;
b) Farmer to retailer or village trader to consumer;
c) Farmer to wholesaler to retailer to consumer;
d) Farmer to village trader to wholesaler to retailer to consumer;
e) Farmer to co-operative marketing society to retailer to consumer;
f) Farmer to a government agency (FCI, etc.) to fair price shop-owner to consumer;
g) Farmer to wholesaler to flour miller to retailer to consumer.

The channels of paddy-rice and pulses are broadly the same, except that rice millers or dal millers come into the picture before the produce reaches retailers or consumers.

10.7 THE PERFECT MARKET CONCEPT

The general nature of these market structures is familiar- perfect knowledge, no lag, large no. of firms, stadardised or homogenous products, and no exercise of monopoly powers. Actually the requirements for a perfect market are some what less restrictive. The essential conditions are:

1. Large no. of buyers and sellers are there in the market
2. Perfect knowledge by all buyers and sellers
3. Each buyer and seller acts in an economically "rational" way, disregarding any influence of his actions on price, and
4. Free entry in all directions.

Of course, all markets in real life operate with some degree of imperfect knowledge and with lags and frictions, and some have important elements of monopoly. In spite of this, the concept of the perfect market is important. Its abstraction permits us to focus attention on and to understand the general nature of many market forces. It is a fair approximation to reality in some markets and, perhaps, especially for many agricultural markets. It has some "normative" values associated with the concept of economic efficiency and so, may be useful in economic planning. Finally, it provides an essential background for understanding imperfect markets.

10.8 ROLE OF MIDDLEMAN

Middlemen are those individuals who specialize in various marketing functions involved in sale and purchase of goods as the commodity moves from producers to consumers. They may operate as individual, partner proprietors, co-operatives or non cooperative corporations. The activities and functions that most people visualize as "agricultural marketing" are those related to the movement of commodities from primary producers through to ultimate consumers. Some farm commodities move directly to ultimate consumers, but most of products require some additional sorting, grading, storing, and processing before they are ready for consumption. Transportation and handling takes place as commodities move from one stage to another in the marketing system. Storing and processing may take place at several different stages. This involves expenditure. In fact, marketing process is expensive. Nearly 40 percent of costs are the marketing costs. In case of perishables, the marketing cost is very high.

Many people in developing countries see the activities being performed by middlemen, add little value but charge heavily. It is reported in many studies that there are excessive "hands" in the marketing process, but most recognize that the marketing functions of transporting, storing, and processing, and the provision of place, time, and form utility, are essential – whoever performs them.

Often, marketers or middlemen are looked upon as parasites in the economy. They do, however perform essential functions and the system should permit equitable earnings for those performing needed services. Thus, The marketing systems provide a livelihood for people who perform the various marketing activities, and should yield reasonable returns to the capital and management skills devoted to them. Transportation and storage provide place and time utility--bringing goods to the people where and when they want it. Processing increases form utility—preserving the life of commodities like food and making them available in more convenient ways. It matters little who performs these kinds of functions—the farmer himself or his wife who sells their commodities in the market place, his cooperative association or a marketing board, the trucker or miller or baker. All have a right to expect payment for their services and some return on their investment in facilities needed to perform the services. As marketing organizations grow in size, requiring more capital and specialized management, returns on investment and payment for management skills become increasingly important in the interest of efficient market performance.

In India, various middlemen, in agricultural marketing, who perform marketing activities in between producers and consumers can be classified as

I. Agent Middlemen
   1. Brokers
   2. Commission agents

II. Merchant middlemen
   1. Wholesale traders
   2. Retailers

III. Speculative middlemen

IV. Processors and manufacturers

V. Facilitative middleman.
   1. Hamals/Labour
   2. Weighmen
   3. Transporters
   4. Graders
   5. Communication agencies
   6. Advertising agencies

Their description is as follows:

I) ***Agent Middlemen:*** These are those individuals/agencies which act as representatives of their clients like traders or producers. They earn their income through sale of their specialised services. They charge commission/ brokerage in sale or purchase activities. These are of two types namely brokers and commission agents. The difference between two is very little.

1. *Brokers:* These agents work for a commission on behalf of other participants. They operate at all levels in marketing chain. Typically, they work for a flat rate or percentage (of the selling price)/ commission. They charge brokerage from buyers/sellers or both depending on services provided by them. They bring together the sellers and buyers. They do not work in regulated markets and where the sale is through open auction method. They do not have establishments in the markets.

2. *Commission agents:* They are usually granted broad powers by those who send commodities to him. They normally take over physical handling of products, arrange for the terms of sale, deduct their fee from the sale proceeds and remit the balance to sellers/farm producer. They also advance loan to the farmers/itinerant traders on the condition that produce to be sold will be routed through them. Commission agents are of two types namely Kuchha Arhtya and Pucca Arhtya. Pucca Arhtyas normally acts on behalf of wholesalers/traders/ processors/oil millers who purchase the quantity in bulk through these commission agents. They have their shop, godown and also some times guest house of their own for the farmers in the markets, they act as 'A' class traders.

II) ***Merchant Middlemen:*** These are those individuals who purchase and sell the products on their own and bear the market risk. These are mainly of two types:

1. *Wholesalers:* These traders purchase in bulk either at their own in the market or from producers/ itinerant traders or through commission agents. They sell to the retailers/processors or dispatch to other markets also. They bear the market risk.

2. *Retailers:* Retailers are those traders who normally purchase from the wholesalers either on cash or credit. They divide up large amount of produce purchased and sell it to consumers in small units. They also bear the market risk.

   Itinerant traders/village merchants are also in this category who purchase the produce from those producers/farmers, who do not want to go to markets for various reasons, and sell produce in the nearby market on some profit. They keep them aware of daily market prices.

III)***Speculative Middlemen:*** These **are** those who speculate and take advantage of price movement in the market. Speculative middlemen seek out and specialize in taking price risks and usually do not handle and merchandise. They often attempt to earn their profits from short-run fluctuations in prices. Purchases and sales are usually made at the same level in the marketing channel. For example, a speculator merchant may buy a product/commodity today and sell it back either today or tomorrow in the same market. They may buy and sell commodities in futures several times within the same day. They are professional risk takers unlike merchant middlemen.

IV) ***Processors and Manufacturers:*** These undertake processing activities and thus add form utility in raw or semi-finished products. They many times, use their own buying agents in the producing areas. This group may undertake processing or manufacturing and then wholesaling of their finished products to retailers. Many processors attempt to reach the ultimate consumer through advertising.

The restaurant most often is a retailing establishment in that it sells to final consumers. However, some of these businesses operate as wholesalers, preparing food in large quantities and selling to other retail outlets. And of course these businesses are, because of their preparation and cooking activities, processors.

V) ***Facilitative Organizations:*** These organizations aid the various middlemen in performing their tasks. They do not directly participate in the marketing processes either as merchants, agents, processors or speculators. One group of these organizations furnishes the physical facilities for the handling of products. They also aid in grading, arranging and transmitting payment etc.

1. *Hamal/labour:* These load/ unload the products from vehicles and move them in the markets. They receive their incomes from their physical labour use.

2. *Weighmen:* The weighmen weigh the products in the market and get payment for that.

3. *Transporters:* These move commodities from production point and transport those to consuming points.

4. *Graders:* These facilitate in making the products uniform for better pricing. They charge for their labour used in grading.

5. *Communication agencies:* They help in providing information on various aspects of marketing, including price and arrival information in a market or at different markets.

10.9 MARKETING EFFICIENCY

Marketing efficiency is a degree of market performance. Marketing efficiency is the ratio of market output (satisfaction) to marketing input (cost of resources). An increase in this ratio represents an improvement in the efficiency. The reduction in the cost for same level of satisfaction or an increase in the satisfaction at a given cost results in the improvement in the efficiency. Clark, defined marketing efficiency as having following three components:

i) The effectiveness with which a marketing service is performed.

ii) The cost at which the service is performed.

iii) The effect of this cost and the method of performing the service.

10.9.1 Types of Marketing Efficiency

Traditional efficiency of the marketing system has been looked at two angles:

a) *Pricing efficiency or allocative efficiency*

The pricing efficiency is concerned with improving the operation of buying, selling, and pricing aspects of marketing process, so that it remains responsive to the consumers' directions. The best measure of the consumer satisfaction obtained, from marketing systems output, is what the consumers are willing to pay for it in the market place. If markets are operating efficiently, the prices of the different commodities are related to space, time and form. The prices should not differ among geographical regions, transportation cost and storage cost. Similarly it should not exceed more than the cost of processing. If it differs more than that, then the pricing efficiency is low.

Therefore, pricing or economic efficiency relates to functional deficiency or degree of competition or monopoly. Government needs to police the conduct to prohibit collusion or any other act that hurts the competitive performance.

b) *Operating or technical efficiency*

It indicates use of technology in providing marketing services. In contrast to pricing or economic efficiency, operational or technical efficiency assumes that the output of goods and services is given and focuses on reducing the costs of providing them. For example more efficient use of machine for sorting and grading will reduce the cost of grading. If these costs are lowered, keeping the services at the same level, bulk transport using efficient mode of transport, will reduce the operational cost. Both of above two types of efficiencies reinforce each other for better efficiency.

For example, if in market A cost of say grading is Rs 1.00 per kg and in market B cost of grading is Rs 1.20 per kg, then market A is operating efficiently in respect of grading.

10.9.2 Methods to Measure Marketing Efficiency

Both types of above efficiencies can be reflected in terms of value added and the costs. The marketing services provided will add to the value and the cost involved in providing the service. Thus we can work out the index of output to input for any of the market in order to assess the marketing efficiency. However it is very difficult to assess the services provided in value terms. In other words, it is difficult to assess the value added by an activity during the marketing. However, evaluation of cost is relatively easy.

Index of marketing,

$$E = O/I$$

Where E is the index of marketing efficiency, O is the output (value added or the services provided) and I is the input cost.

Total value added in a marketing system can be taken as the difference in the price of product paid by the consumer and the price received by the producer. If we want to compare the efficiency for two different markets located at a distance, we need to work out this index for both market and see which of the two is an efficient market. Obviously, wherever the index will be more, that market will be efficient comparatively, provided, same type of services are provided. The difference in output and also in input may be due to difference in the technology used or the market competition itself. We also need to find the imperfection in competition. In imperfect market, the prices of output are more due to undue profit charges.

A modified version of marketing efficiency (ME) as given by Shepherd is given below:

$$ME = (V-I)/I$$

Where V is Price paid by consumer, I is the input cost. In this method the difficulty in value added by marketing services is overcome. However, the formula remains the same if approximation is used for value added.

We compare the efficiency of different markets, marketing channels using this method.

10.10 MARKET MECHANISATION – CONCEPT, ROLE AND SCOPE

Mechanization of marketing operations has become popular in almost every human activity. However, the pace of mechanization in India in respect of marketing is slow. Mechanization in crop production has been spectacular especially on large farms. It has also saved farmers from the drudgery of farm operations. Mechanical market operations differ for different commodities. In view of urgency, the farmers have now become commercial minded and therefore the production has also increased. The marketable and marketed surplus of all types of crops has increased. This has created over crowding and congestion in the markets, especially those of food grains.

10.10.1 Role

Higher marketed and marketable surplus of almost all agricultural commodities including fruits and vegetables has expanded the arrivals in the markets. But Indian markets are normally congested. High arrivals have made them more congested especially when commodities do not move faster due to slow and time consuming marketing operation. Mechanisation of various marketing operations in such situation (like that in crop production) is the only answer for swift movement and clearing the markets. The role can be easily seen through followings:

1. The precision in operation by manual labour is not possible. This calls for mechanization so that more uniform goods are available to consumer. This will also facilitate other marketing operations.

2. The operations by manual labour are very costly. But the mechanical operations perform these various activities at reasonable cost. This will help the consumer more.

3. Fast transport of commodities from very far-off places is possible through rail and highways. This will also help the farmers in taking advantage of higher price in a particular market.

4. Drudgery of marketing operation drastically reduces.

10.10.2 Scope

Market mechanization in India is very slow and need special attention for providing variety of services. Today, variety of services with swiftness and that too at low cost are extremely important. All of these could be achieved, provided we go for mechanization. The mechanization for different commodities may differ. The perishable commodities like fruits and vegetables need different kind of mechanization compared to food grains.

Sorting, grading weighing, bagging, stitching and use of conveyor will be very effective in improving operations in the markets. While time saving mechanization is important in perishable commodities like fruits and vegetable etc. less costly operation are needed for non-perishable commodities which are dealt in bulk. Mechanical operations at all marketing stages including mixing of chemicals in the commodities kept in storage (if needed) will reduce the cost tremendously. Thus, there is tremendous scope for marketing mechanization which will enable the marketing functionaries to provide the marketing services with swiftness, at low cost and well in time. It will also help in decongestion of the agricultural markets to a large extent.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. a) Define a market.

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b) What are the necessary condition for market to exist?

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c) What is the role of markets in farm economy in India?

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2. a) Classify the markets on the basis of location.

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b) Write in brief the concept of perfect market.

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3. a) What is meant by marketing channels?

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b) Write various marketing channels of vegetables in nearby market in your area/ district.

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4. a) Write briefly the marketing functions.

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b) Why these functions are important?

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5. a) Explain briefly operational and technical marketing efficiencies.

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b) How the marketing efficiency can be measured?

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6. a) What is meant by market mechanization?

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b) Explain its role in improving the agricultural marketing in India.

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10.11 LET US SUM UP

Markets are very important in smooth conduct of buying and selling operations of any goods and services. These markets play a very important role by giving, directions to the resource use. In fact, a perfect market situation maximizes the welfare of producers as well as consumers'.

Market Prices are the signals that direct and coordinate the decisions of producers, consumers and food marketing firms. These prices are the result of supply and demand forces operating within the framework of an open exchange freely competitive marketplace. There is a tendency for farm prices to return to the supply and demand equilibrium point when disturbed. Shifts in the supply and demand, results in new equilibrium prices.

Competition plays a key role in harnessing the rivalry and the profit- seeking of the marketplace in order that it may serve the public interest. The competitive state of the agricultural markets disciplines firms' conduct, behaviour and practices; encourage new technologies and products; and regulates prices and profit level.

10.12 KEY WORDS

Market	:	Market is an arena for organizing and facilitating business activities and for answering the economic questions: What to produce, how much to produce and how to distribute.
Marketing	:	Marketing is performance of all business activities involved in flow of goods and services associated with inputs and output from initial point of production to ultimate consumers.
Perfect Market	:	A market characterized with large no. of buyers and sellers all engaged in sale and purchase of homogenous products with perfect knowledge of market prices and quantities and no discrimination. Perfect competition is a market structure having above characteristics.
Marketing functions	:	These are specialized business activities necessary to the marketing process.
Marketing channels	:	Alternative routes of product flow from producer to the consumers.
Brokers	:	An agent middleman who facilitate trade but does not physically handle the produce. He is paid fee by the sellers or buyers.
Marketing efficiency	:	A ration of market output (satisfaction) to marketing inputs (cost of performing functions). An increase in this ratio represents improved efficiency, a decrease indicates decrease in efficiency.

Market Mechanization : Performing various marketing functions including loading and unloading using mechanical means is market mechanization.

10.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) Your answer should include definition of market.

   b) The conditions included are existence of commodity, buyers and sellers and medium of exchange.

   c) Your answer should indicate/explain how the market gives direction to produce more beneficial commodities, through price.

2. a) Your answer should include the explanation village, primary, secondary, terminal and sea board markets.

   b) Your answer should include the definition of perfect market and also the conditions for perfect market

3. a) Your answer to this question should include definition of marketing channels (routes through which agricultural produce passes from farmers to ultimate consumers.

   b) Explain the various marketing channels of commodity sale to consumer such as

   Farmer —> co-operatives —>wholesaler —> retailers —>- consumer

   Farmers —> consumer

   Farmers —> Commission agent & or —> wholesaler —> consumer etc.

   From your own experience you should write which of the channels in prevalent in your nearby market.

4. a) The answer to this should includes exchange function, physical function and facilitating function along with sub functions of each of these.

   b) Your answer should include the help in smooth sale and purchases (as valuation becomes easier), both farmers/intermediaries and exporters gain through this and gives income and employment.

5. a) Your answer should include operational and technical efficiencies along with examples.

   b) The answer should include formula for marketing efficiency index including revised version of marketing efficiency.

6. a) The answer should include the meaning/definition of market mechanization with some example.

   b) Under this you should explain fastness, economic, uniformity and better pricing through mechanization.

10.14 SOME USEFUL BOOKS

1. Acharya, S.S. and Agarwal, N.L. (1999) Agricultural Marketing in India. OXFORD & IBH, Co. Pvt. Ltd., New Delhi.

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UNIT 11 MARKET INFORMATION SYSTEM

Structure

11.0 OBJECTIVES

After reading this unit, you should be able to:

- explain concept of market information system;
- describe importance of Marketing information system to various people engaged in marketing;
- know why information system is needed and what is the existing marketing information system in India;
- explain difference in marketing information and marketing intelligence;
- know various agencies providing marketing information in India, lacunae in marketing information system and how it can be improved; and
- describe components of marketing environment and various sub-systems of marketing information system.

11.1 INTRODUCTION

In traditional subsistence economy the farmers had little marketed and marketable surplus which they sold in the local markets only. They knew their customers first hand. They knew consumers' preference and their paying capacity etc. by being around them. Today, the consumers are wide spread in domestic and international markets with better paying capacity. This has offered a good market opportunity to the farmers. The remarkable development of roads, transport and communication have further added to the market opportunity. An agricultural commodity producer located in a corner of the country can plan the sale of his agricultural products through out the country or even globally. But for better prices he must have knowledge of potential buyers and prices in various markets. This information provides him opportunities for high sale prices and greater profit. In fact, we can say that market knowledge is the power for higher income even to the small farmer or a tiny producer. Thus, a farmer / manufacturer can harvest rich returns if he is able to take right marketing decisions, given the market information. All producers, manufacturers, and all other marketing intermediaries, include the organizations providing marketing facilities, utilise marketing information to run the business more profitability. However, Market information requirement of various groups of people engaged in marketing may vary.

Farmers, businessmen, administrators, and legislators have come to rely more and more on statistics to tell them what's happening, to show where their economic problems are, and to assist them in finding answers or serving as a guideline both for current activities and planning ahead.

11.2 CONCEPT AND DEFINITION

Marketing information system is system of collecting and analysing information related to marketing of goods and services. It consists of people, equipment, and procedures to gather, sort, analyse, evaluate, and distribute pertinent, timely and accurate information for use by marketing decision makers. A marketing information system collects the information on various related aspects of marketing environment such as marketing channels, competitors, prices, arrivals, grades, standards etc.. For international marketing it collects information on prices, quality, standard, grades and legal aspects for products sale in importing countries.

It combines this external information with his own business information including his capacity and capability (internal) to take the right decision on what, where, when and how to sell (from farmer's point of view or any other seller's/manufacturer's point of view).

Market information may be defined as a information on all marketing aspects important from selling or buying point of view. It includes all facts, estimates, opinions and other information which affect the marketing of goods and services.

Authentic market information is the life blood for profitable marketing/sales. Market information agencies judge the pulse of Market (whether price is high and sale is active or sluggish?), measure the temperature of markets (prices whether rising or fallings?), and monitor the market's pressure (whether supplies are adequate, short or in glut?). The market's history is recorded in statistical data series, and agencies offer a prognosis or estimate of the markets' future health.

Market information is a facilitating marketing function, and market intelligence is essential to a smooth and efficiently operating marketing system. Accurate and timely market information facilitates market decision, regulates the competitive market process and lubricates the marketing machinery.

All those who produce, buy and sell agricultural products are continuously amassing, revising and using market information on prices, supplies, demand, and other market conditions.

11.3 IMPORTANCE AND NEED OF MARKETING INFORMATION SYSTEM

11.3.1 Importance

After learning the definition you should be able to understand the role and need of MIS to various groups of people engaged in marketing. Information for management of commercial farming is very important from profit point of view. In fact, to manage a business very profitably is to plan and manage its future, but to plan and manage future is to manage the relevant information. Its importance for various group of people can be judged from the following:

a) *Farmer-producers:* Market information helps in improving decision-making power of the farmer. A farmer is required to decide when, where and through whom he should sell his produce and buy inputs. Price information helps him to take these decisions.

b) *Market middlemen:* Market middlemen also need market information to plan the purchase, storage and sale of particular commodity. On the basis of market information/ data, they project their estimates and take decisions about whether to sell immediately or to stock goods for some time, whether to sell into the local market or go in for import or export, whether to sell in their original form or processed form. The loss/failure of business can partly be attributed to either the non-availability of market information or its inadequate availability, analysis and interpretation of market information. Co-operative marketing societies operating as commission agents make use of market information for advising their members so that they may take decisions on when to sell their product.

   Processors make use of market information and plan their purchases so that they may run their plant continuously and profitably. They can also work out the inventory of a product that should be maintained for a particular period of time.

c) *General economy:* In fact, market information is also beneficial for whole economy. There is always need for a competitive market process for all commodities. The competitive process contributes to the operational efficiency of production and marketing. However, a perfectly competitive system is difficult to obtain; but the availability of market information contributes towards the competitive situation. In the absence of this system, different prices will prevail, leading to the profiteering by specialized agencies. The business of forward trading is based on the availability of market information.

d) *Government:* Market information is essential for the government in framing its agricultural production policies, in the regulation of markets, buffer stocking, import-export, prices, mechanization and control policies.

11.3.2 Need of Marketing Information System

During the past century three developments have taken place that necessitated need for more and better marketing information system.

a) *Markets expanded from local to national and international marketing*. The fast infrastructure development has remarkably expanded the market. The producers can take the advantage of this expanded market. When the commercial farmers expand their business or area of operation to meet demand, they need more formal system for collecting market information and analyzing it. The WTO has opened a new chapter for developing countries for export of agricultural products in global market provided developed countries do follow the code of conduct and help in establishing fair trading system.

b) *Change from buyers needs to buyer wants*. As the income of the buyers increase they become more choosy and need variety of goods. In fact, today, consumers need more diversified food basket. The increase in number of buyer also result in large opportunities. However, seller find it harder to predict buyers response to different features. Obviously more detailed information on consumers' wants can help the business enterprises.

c) *Change from price to non-price competition*. As sellers increase the use of branding, products differentiation, advertising and sales promotion, they require more information on effectiveness of these marketing tools.

Marketing information need can be assessed through the following questions:

- What type of decision you are normally required to take?
- What type of information you need to take these decisions?
- What type of information do you regularly get?
- What additional type of information you need?
- What information you want daily, weekly, monthly and annually?
- What five most important improvements can be made in the present marketing information system?
- What information do you need for export of specific product?

Both government and non government organizations are engaged in collecting and disseminating the information world wide. Better endowed Farmers/Traders/ firms collect the market information through their own resources.

A rational farmer or trader will try to maximize his profit through sale by integrating all the markets information. Market information pertaining to a set of markets helps the users in taking decision on what, where, when and how to sell. An intelligent farmer/trader monitors the movement of price as well as demand and supply of different agricultural commodities overtime and across various markets including international markets and then takes the decision to the best of his advantage under national and international macro environment. Such market information on commercial agricultural products normally consists of different products, grades, standards, factors affecting market forces, prices in different markets for different grades and the competitors of similar products. Thus, this will include information on all the micro and macro, socio-economic and political factors that affects the decision-making in agricultural trade.

The role of the marketing information system is to assess the information needs of farmers and traders, develop the needed information and distribute the information in time to the various clienteles i.e. farmers, processors, traders and consumers. The needed information can be developed through collection of information by survey, marketing intelligence activities, marketing research and marketing decision support analysis.

Different countries have developed marketing information systems with variations depending on the amount of money invested in the system. Those systems are also related to planning priorities, and the type of commodity produced. Most countries in Asia operate a marketing information service with the express aim of promoting efficient marketing and raising farm incomes. The form it takes varies according to the level of economic development, and especially the extent to which agriculture has changed from subsistence to commercial farming.

11.3.3 Need for Marketing Information In India

India has varied agro-climatic conditions which enables it to produce all kinds of agricultural crops in various parts of the country at different period of times in an year. But, the forward linkage is India is very poor and the farmers sell the produce in nearby/local markets or in the village itself. Many a times heavy supplies come to the local market which leads to low price and thus low profit while price in other/distant markets is high. This high price in other markets can be a fortune for any farmer. But the farmers not have the information on such prices. The local market traders also exploit the poor farmers through various mal practices.

National marketing information systems usually provide price information through the mass media, such as newspapers and radio. However, it is not clear how useful such information is to the farmers. It is believed that information is either not available or available in different forms.

The need for market information on agricultural products and markets is more important in agricultural economy like India where large amount is produced by crores of small and marginal farmers. Their income depends on the sale proceeds of agricultural commodities. Thus, marketing information will help Indian farmers and other market functionaries make profit oriented decisions through what, how, when and where to market produce and what price to expect under prevailing conditions. The farmers who understand market trends and market opportunities have a better chance of getting potential returns and success. As a matter of fact, marketing information plays a vital role in the functioning of the whole market system. Helping farmers in India through market information ensure that produce goes to markets where there is a demand for it. It shortens marketing channels and cuts down on transport costs. It helps ensure that each marketing transaction is a fair one, and that all participants share the risks and benefits. However, this does not happen if marketing information is distributed unequally, as is generally the case in India where large number of small size farmers sell to local traders or to the markets with few traders for various reasons especially lack of resources and market information. The farmers then end up bearing the greater part of the risk, while the dealers end up with the greater part of the profits.

Recent advances in information technology will help small farmers, large farmers or traders with the marketing information they need to make right decision. However, farmers may not benefit from sophisticated facilities, if the system is poorly managed or not designed for their needs in terms of infrastructure. It is not enough for marketing information to be collected: it must also be disseminated in a form accessible to clients and adapted in their decisions.

In many marketing information systems, regional data is transmitted to a central national facility where it is processed and amalgamated with similar data from all over the country. The result is useful to those working for central government agencies, who need to know what is happening over the whole country. It is of less value to the farmers or consumers in the rural areas. Farmers are interested mainly in prices in local markets where they sell their goods. Big traders, Associations/ houses take advantage of such national and international marketing information.

11.3.4 Central Scheme for Marketing Information in India

In India, the Directorate of Marketing and Inspection (DMI) headed by the Agricultural Marketing Advisor, Department of Agriculture & Co-operation (DAC) implements agricultural marketing policies and programmes of the Government of India. It undertakes:

- Standardisation, grading and quality control of agricultural and allied produce
- Market research and surveys
- Provides technical support in regulation, planning and designing of physical markets.
- Training of personnel in agricultural marketing in the country
- Promotion of cold storages
- Administration of Meat Food Products Order
- Marketing extension, consumer education etc.
- Market Information network.

It also liaise with the State Agricultural Marketing Boards and Directorates for Agricultural Marketing Development in the country, which have been established to ensure proper planning and development of agricultural marketing including implementation of State Marketing Legislations which define local market practices, market charges payable to various functionaries, license the functionaries and promote the development of orderly marketing. The dissemination of market information is common function of Agricultural Produce Marketing committee (APMC), which is performed through displaying of the prices prevailing in the market on the notice boards and broadcasting through All-India Radio, etc. This information is also supplied to State & Central Government from important markets. The statistics of arrival, sales & prices etc. are generally maintained by APMCs of various markets in India.

By and large the States and Union Territories are providing some market information in one form or the other for the benefits of market users like producers, traders and consumers. However, the information is collected and disseminated by use of conventional methods which cause delay in communicating the information to different target groups, adversely affecting its utility. The farmers are also not able to know about the prices prevailing in other markets. Many Market Committees still disseminate information in respect of their own markets only. The farmers are, therefore, left with no alternative but to dispose of their produce in the nearest market, even at throw away prices, because of either not available or delayed market information.

Therefore there is an urgent need to bring improvement in the present marketing information system by linking all APMCs, State marketing Board and State Directorates of Agricultural Marketing and DMI of Ministry of Agriculture. It is felt that investment on network of about 7000 Whole sale Agricultural Produce Markets in the country will facilitate globalisation of Indian farmers. In view of this importance, the Department of Agriculture and Co-operation in Ministry of Agriculture Government of India (GOI), under DMI, has sanctioned a Central Sector Scheme named as Agricultural Marketing Information Network (AGMARK-NET) at an estimated project cost of 10 crores to link at present 770 agricultural markets besides 40 Agricultural Marketing Boards/Directorates in the beginning during 2000-02. The objectives of this Scheme are:

- To establish a nation-wide information network for speedy collection and dissemination of market information for its efficient utilisation.
- To computerise data on market fee, market charges, total arrivals, arrivals by agencies, prices (variety wise / quality wise), storage, dispatches with destination, mode of transportation, costs, sold and unsold stocks, sources of supply with destination, method of sale, payment, weighment, grading facilities, quantities graded, market personnel (trained/ untrained), market functionaries, market finance, development programmes, infrastructure facilities, constitution/composition of Market Committee, income and expenditure and other activities of the Agriculture Produce Market Committees, State Marketing Boards and Departments.
- To ensure flow of regular and reliable data to producers, traders and consumers to derive maximum benefit of their sales and purchases.
- To increase the efficiency in marketing by effecting improvement in the existing market information system

11.4 TYPES OF MARKET INFORMATION

Market information is of two types:

i) *Market intelligence:* Marketing intelligence is different from regular marketing information or marketing research data. It may form part of marketing information system but it is special in the sense that it gives strategic information in a flash and is quite often related to competitors' activities. The nature of the marketing job necessitates a good intelligence system. Broadly, marketing intelligence furnishes information on changes in market conditions, changes in customers' requirement, emerging strategies of competitors and emerging opportunities in the business Marketing intelligence may be gathered by marketing executives directly or through field sales managers. Occasionally, it is also purchased from external agencies which provide marketing intelligence services. In what so whatever manner it is collected, it is essential to have a reliable and efficient system for gathering and using the intelligence. If there is too much delay in the process, the marketing intelligence loses its significance.

If it is gathered and used properly, marketing intelligence will serve as a pathfinder.

ii) *Market news:* This term refers to current information about prices, arrivals and changes in market conditions. This information tips the farmers to take decisions about when and where to sell his produce. The availability of market news in time and with speed is of utmost value. Sometimes, a person/trader who gets the first market news has a substantial advantage over his fellow-traders who receive it late. Market news quickly becomes obsolete and requires frequent up dating.

11.5 AGENCIES PROVIDING MARKET INFORMATION

The collected information has no meaning until it reaches the persons who need it. The agencies/ sources through which market information is disseminated are:

a) *Personal contacts:* This is the most important source of dissemination of market information. Information is given orally, i.e., by one businessman to another businessman, by a businessman to a farmer, or by one farmer to other farmer.

b) *Post and telephone:* Businessmen get information from other markets on the telephones. Commission agents convey the information on the prices of different commodities to their client-farmers on postcards. They fill the rates on these postcards and post them daily or some time at intervals.

c) *Newspapers:* The newspapers in English, Hindi and regional languages publish the wholesale prices of important agricultural commodities in the selected markets of the country/State. In addition, the Economic Times and the Financial Express contain a lot of information on the various aspects of marketing including prices.

d) *Magazines:* Magazines, such as the Eastern Economist, Commerce and Capital, are important weekly trade journals, which collect information on trade.

e) *Government agencies' reports:* The regulated markets, the Agriculture Marketing Department in the States, the Directorates of Economics and Statistics in the States, the Directorate of Marketing and Inspection, Government of India, and the Directorate of Economics and statistics, Ministry of Food and Agriculture, Government of India are some of the government agencies which disseminate the collected market information through their regular publications and broadcasts on All India Radio.

f) *Price bulletins:* These are issued daily, weekly, or every month. The important bulletins through which price information is disseminated are: Bulletin of Agricultural Prices (Weekly), Agricultural Situation in India (Monthly), Agricultural Prices in India (Annual), and Bulletin on Food Statistics (Annual). The monthly situation and outlook ports are published by the Directorate of Marketing and Inspection, Government of India.

g) *Radio and television:* The information on the market situation in respect of prices and arrivals of commodities in major markets are regularly telecasted. Almost all channels now have the slot for market information. Several State Governments and National Information Centres of the

Government of India have initiated interlinking the markets with NIC-NET with view to ensure the quick flow and accessibility of market information on prices and arrivals. The information on this is also available on internet.

h) *Through internet:* Internet has become a main source of market information. All the world major markets' grade-wise prices and arrivals of various commodities on different days are available. Even the origin wise and variety-wise information is also available through internet. Directorate of Marketing and Information (DMI) has been pioneering in this aspect.

i) Krishi channel: Recently a new Television Channel dedicated to agriculture has been proposed. The channel will cover production and marketing including international trade issues. The farmers have high hopes from it. This will also extend the marketing information in future.

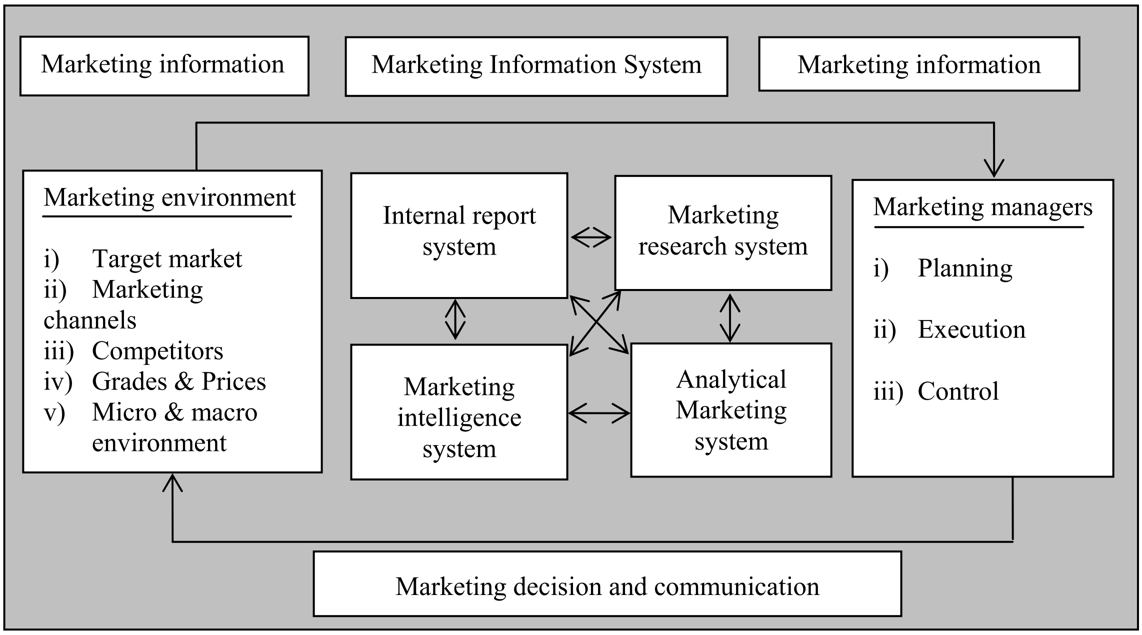
j) Kisan call centres: Kisan Call Centres will be spread throughout the country in various states/zones. These will have direct link with experts on various agricultural aspects including agricultural marketing, in State Agricultural Universities/ Research Institutes or a panel of experts at these centres only. Any farmer can seek information/ ask any question related to agriculture at any time by dialling 1551, a toll free number. The solution to his problem will be suggested on line or with in 24 hrs depending upon question and experts availability.

11.6 COMPONENTS OF MARKETING INFORMATION SYSTEM

Instead of a plethora of unrelated data on market information one needs pin pointed information which farmers/traders/firms combines various inputs with internal information and presents integrated report for him. Thus every farmer or trader must organize a rich flow of information or they must search for relevant information. Conceptually in a competitive world they must study the information need and design marketing information system to meet its demand. The various components of marketing environment are

- Target market
- Marketing channels
- Competitors
- Publics
- Microenvironment forces and
- Macro environment forces.

They must collect and monitor marketing environment and market trend information and analyze through four subsystems making up the Marketing Information System. These subsystems are presented in the following diagram.



Let us take a closer look at above four subsystems.

i) *Internal report system:* Every farm/firm manager produce internal report showing their current production, sales, cost, inventory, profit and capabilities. They plan the information need and design to collect it.

ii) *Market intelligence system:* This system provides the farm/firm/coy with happenings data in the commercial environment. The farm manager get the information through reading newspaper, reports, internet, telephone/ mobiles, telegraph, suppliers, distributors, specialist, panel of experts, even purchase the intelligent from outside, or keep their own staff to get information. Farmers normally need the information of standard/grades, prices, transport, channels, strategies, legal system, institutions and competitiveness.

iii) *Marketing research system:* It is the systematic design, collection, analysis and reporting of data and finding relevant information specific to situation facing the firm. The managers either get the data analyzed or study the specific situation himself. They measure market potential based on various marketing components and analyze it to take decision.

iv) *Analytical marketing system:* It consists of advanced techniques for analyzing marketing data and problems. The data is available in the farm records/firms data bank. Farm/firm manager try to find out major variables (and their significance) which affect the sales potential. They thus find the potential markets and the segment of the markets through analytical system. Then they plan for marketing of produce. They choose the mode of transport, distributor and channels.

Based on analysis of market information they can plan and execute the plan, monitor and keep control over the business.

11.6.1 Steps Involved in Designing MIS

- Identifying the broad information requirement of the organization.
- Classifying the information requirement and identifying whether it is for planning purposes or control purpose.

- Evaluating the cost of collecting and processing the information.
- Comparing the cost verses benefits.
- Decoding the frequency and timing of collection of information.
- Identifying the sources of information.
- Designing the mechanism/procedure for gathering, processing, storing and retrieval of information.
- Analyzing and interpreting the information and disseminating it to the right persons at the right time and in the right manner.
- Monitoring, maintaining, reviewing and improving the system.

11.6.2 Marketing Information Benefits

Various benefits that flow from marketing information are listed below:

- It helps marketing planning by making available reliable information on the external environment and the internal realities of the company.
- It helps effective tapping of marketing opportunities and provides effective defence against emerging marketing threats.
- It helps early spotting of changing trends; it provides market intelligence to the firm.
- It facilitates the development of action programmes for achieving goals.
- It helps the farmer/trader adjust their products and services to the needs and tastes of customers.
- It helps the farmer/trader control their marketing activities.

The quality of marketing decisions are decided to a great extent by the quality of marketing information available to the decision maker.

11.6.3 Criteria for Evaluating Market Information

For maximum benefits, the market information must meet a number of criteria. Some of those are described below:

1. *Comprehensive information:* The information must cover all agricultural commodities and markets including international markets. A reasonable and comprehensive information includes prices, price trends, production, supply movements, stocks, and demand conditions at each level of the market for a product. Providing such a mass of information, especially under the constantly changing conditions is a formidable and expensive task.

2. *Accuracy and trustworthiness:* Information must be accurate and trustworthy. However by nature, market information can never be 100 per cent accurate, but it must be an honest market appraisal in order to earn the trust of information users. Constant efforts are made to improve the accuracy of market information and news services.

3. *Usability:* Information also must be relevant and in usable form. It is not enough to simply collect a number of reports. Information must be collected, packaged, and disseminated with the user's interests in mind.

Much market information goes unused because it is not in usable form. In such case the efforts made in collecting the information go waste.

4. *Confidentiality:* The information should be confidential to whom it is collected. The information revealed under this situation of confidentiality will be more correct and may assist in drawing policy implications. The names of firms, to whom the market information is collected, should not be leaked out.

5. *Timeliness:* Market information must be timely, in the sense of being relevant to current decisions, and must be speedily transmitted to users. Much market information is unusable. Futures market traders require minute-to-minute market information.

6. *Accessibility:* Each interested party like farmers, consumers, government officials and marketing agencies should have equal access to all the information relevant to the bargaining and marketing processes.

7. *Relevance and clarity:* Market information must be relevant and clear.

8. *Objectivity:* It should convey objective message.

9. *Strategic value:* It should be conceived and used as a marketing decision support system.

10. *Economic:* It must be economical. In other words it should be cost effective

11.7 LACUNAE IN MARKET INFORMATION

Although sellers need pin pointed marketing information. However, such information is normally highly subjective. The major lacunae in existing market information are as follow:

- Lack of information of the right kind. Sometimes right kind of information is not available and is very difficult to under stand by the illiterate farmers in India. The market reports are also incomplete and bulky many times and do not serve any purpose.
- The available information are not in desired form. Most of the information pertains to wholesale marketing. One also needs information of prices at retail level or quality or pack size.
- Lack in timely dissemination of market information. Most of the time, the news reported is so late that it is of no use. Inadequacies of information especially on phyto-sanitary aspects under changing global scenario prevents wider access to international market by Indian Exporters.
- Reliability of the information is very poor. The biasly collected and disseminated information further adds to woe.

11.8 HOW MARKETING INFORMATION CAN BE IMPROVED

Following are some of the suggestions for improvement in the existing market information system, so that the marketing system for agricultural commodities becomes orderly, efficient and effective in helping the agencies involved in marketing:

- Uniform units should be quoted. A standardized system of quoting the prices of the different varieties, grades and weight of the commodity should be followed instead of many time quoted in the local units, so that the prices may be compared over time and space.

- The prices announced on FM/AM/ local AIR should cover more local markets rather than important secondary and terminal markets located in far off areas. The frequency of, and time allotted for the announcement should be increased so that the farmers may benefit from the information. The broadcast time should be such that the farmers can listen to the announcement and take decisions about consignment of the produce to the market.

- Prices should be displayed on notice boards at important public places like hospitals, schools, panchayat ghars, etc.

- The staff posted for the collection of market news should be knowledgeable and trained. There must be thorough and frequent check to ensure that guess work, manipulation and bias are excluded.

- Market news should have no place for rumours: Rumours are harmful for the cultivators.

- Market news provided should be as fresh as possible so that it may create confidence and trust among the users.

- A correct and intelligent interpretation of market information should be made and announced. This is very important, for farmers may not be able to interpret correctly.

- There must be proper-coordination between market intelligence and policy making departments so that the later may better understand the problem and can make such adjustments in the information as may be called for.

- In many markets, a price range is reported instead of a single price. This is so because of the variation in quality and the large number of transactions taking place in the market. The range is very wide, and may not serve the purpose of the users. Therefore, the price range should not be very wide or ambiguous.

- The users of market information should be trained from time to time as the development takes place. This will help them to take the best advantage of market information.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. a) Define a market information system.

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b) Explain its role in increasing the income of the farmers and exporters.

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2. a) Explain various agencies/sources through which the market information in India is available.

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b) Which one is the best for farmers in your view and why?

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3. a) Outline various steps for designing marketing information system.

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b) Enumerate MIS benefits.

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4. a) What is the lacunae in marketing information system?

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b) How MIS can be improved?

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5. a) What are the components of marketing environment?

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b) Explain the various sub-systems of market information system.

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6. a) Why marketing information system is needed?

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b) How MIS can be evaluated?

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11.9 LET US SUM UP

Marketing information is extremely important in commercial agriculture. Its importance has further increased as a result of opening of WTO chapter in the history. The farmers/ Traders in India increase income and employment by strategic planning for domestic marketing. Their income will increase through external trade especially in commodities in which it has comparative advantage. Small farmers can take a collective venture for their benefit through the group action or through co-operatives. Thus, marketing information is a powerful tool for enhancing the income of producers, processor, traders or any other firm.

11.10 KEY WORDS

Market information (MI)	:	is the information/data on various marketing aspects that is necessary for taking decision for profitable selling of the products.
Marketing information system (MIS)	:	Marketing information system is system of collecting and analysing information related to marketing of goods and services.
Directorate of marketing and inspection (DMI)	:	An organisation of Government of India under ministry of agriculture that looks after various aspects of agricultural marketing.
APMC (Agricultural produce marketing committees)	:	It is committee that looks after functioning and facilities in the defined marketing area (normally a whole sale market area).
Agmarknet	:	It is a market information network which has linked large no. of agricultural markets in India.
Market intelligence	:	Marketing intelligence furnishes information on changes in market conditions, changes in customers' requirement, emerging strategies of competitors and emerging opportunities in the business that helps in furtherance of seller's objective.
KCC (Krishi call centres)	:	These are specially created centres which provide information on calling them.
Components of MIS	:	Components are the sub-systems of MIS which collect and analyse the market information that helps in sellers decisions to plan, execute and control.
Lacunae of MIS	:	Shortcomings of MIS.
Price bulletins	:	These are special publications giving information on prices of various commodities prevailing in various markets.
Micro environment	:	Marketing environment relates to individual market/commodity such as existing traders, practices, standards, grades, rules and regulation etc.
Macro environment	:	Macro environment will include legal aspects, phyto-sanitary aspects, grades, preference and practices in a state markets /country markets.

11.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) Your answer should include MIS definition.

   b) Your answer should include how Marketing Information is able to increase income of the farmers (both for domestic and international marketing) as well as exporters by taking right decision based on objective judgement.

2. a) Your answer should include news paper, telephone, posts, magazines, bulletins, display boards, internet as agencies/sources of marketing information.

   b) Answer to question of best agency/sources will be based on your own judgement but you should explain why the agency or source suggested by you is best.

3. a) Answer to this question should include; what information is required, what sources of information are available, mechanism to collect, analyse, process and interpret collected information, sources-wise costs comparison, evaluation of adopted MIS.

   b) While answering benefits of MIS you should explain how it helps in planning, tapping opportunities, meeting trend of preferences of consumers, catching to needs for goods and services controlling of marketing activities and increasing the income of farmers/ intermediaries and the welfare of the consumers.

4. a) Your answer should include the points; inadequacy of information, lack of right information, unavailability of information in desired form, authenticity of marketing information.

   b) Your answer should includes suggestion on uniformity in quoting and displaying prices, quality, grade and variety wise prices in local markets, recruiting knowledgeable staff, reliability of information and proper co-ordination.

5. a) Components of marketing environment will include target market, marketing channels, competitors, grades & prices and other micro and macro environment.

   b) Your answer should include internal reporting system, marketing research system, marketing intelligence system and analytical marketing system including their functions.

6. a) Your answer should include usefulness of MIS to various marketing functionaries including farmers and exporters.

b) Your answer should include evaluation in terms of fulfilment of required information, timeliness, relevance, clarity, accuracy, trustworthiness, strategic value and cost effectiveness.

11.12 SOME USEFUL BOOKS

1. Acharya, S.S. and Agarwal, N.L. (1999) Agricultural Marketing in India. OXFORD & IBH, Co. Pvt. Ltd., New Delhi.
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3. Laudon Kenneth, C. and Jane Price, Laudon (1996) Management Information System. Prentice Hall Publication. N.J., USA.
4. Parsad, Jagdish and Prasad, Arvind (1995) Indian Agricultural Marketing: Emerging Trend and Prospects: Mitall Publication, New Delhi.
5. Ramaswamy, V.S. and Namakumari, S. (1999) Marketing Management Planning, Implementation and Control. MACMILLAN India Limited, Delhi.
6. Saxena, Ranjan (1997) Marketing Management. Tata McGraw Hill Publication. New Delhi.

UNIT 12 MINIMAL PROCESSING

Structure

12.0 OBJECTIVES

After reading this unit, you should be able to understand:

- consumer and market trends in the market that have favoured minimal processing, its advantages;
- key requirements of minimal processing; and
- quality maintenance in Minimal processing.

12.1 INTRODUCTION

The present day food processing industry is moving with a fast pace. The food market today is more competitive, consumer driven and technologically advanced. Compared with the market place of 25 years ago, it has more processed fruit and vegetable products and more innovative packaging. New development in scientific research, consumer demands, taste preferences and technological advances in food processing are some important factors affecting the food industry and new product development**.** Progress in scientific research and food biotechnology also has played a tremendous impact. The present day consumer is more health and quality conscious and more averse to traditional chemical preservatives. The way he perceives the food is also changing. This has had a dramatic impact on food processing technologies. Food processors are exploring new processing and preservation technologies to suit the changing needs of consumers. This has left processors with less flexibility in choosing preservatives and preservation methods. Newer methods of processing and packaging material are being tried to suit to the changing needs of consumers. Minimal processing is one such technology that has arisen because of the changing needs and need for fresh and quality products. Minimal processing (MP) in layman's language are precut fruits and vegetables which are packed in suitable packaging material that permits suitable shelf-life and fresh like characters. Before we see what is minimal processing, let us see its background and examine some factors that have changed the consumers and in turn the food industry.

Background of minimal processing

Need for minimal processing in the present day can be traced back to factors like changed life styles, demographic patterns and more working women and more income. Let us se them in detail.

Changing life styles and demographic patterns

The present day families are nuclear and more fragmented compared to then the families of earlier days. The joint family system has broken apart and nowadays more nuclear families are seen. Smaller families have different needs then joint families. The concept of unitized packaging instead of bulk packaging has arisen due to this change in family structure. This is in turn putting more demands on food processing industry. Smaller families can easily opt for ready to meals then joint or big families. Have you observed that the demand for bakery segment foods has been rising because consumers are asking for more take away meals and snacks rather than traditionally home-cooked set meals. Pizzas, burgers, patties and other confectionary items have put bakeries as major business sectors. These items are becoming increasingly popular among youngsters and college going students.

Apart from this there are changes in life styles and populations too. There are more working women in cities. They have less time for kitchen. Thus more demand for convenient food items. Also we have more older people in population. This group has different food requirements then the younger population.

More working women and more incomes

Since both men and women are working and there are dual incomes in the families. This is probably the reason for more eating out habits seen nowadays. This has also made the present consumer more adventurous who likes to try more different types of product. Consumer in metropolitan cities has developed taste for Chinese, Mexican, Italian, apart from our traditional south Indian and Gujrati foods. The present day scenario was very different from market place twenty years ago.

Need for convenience and quality

Convenience and Quality are the buzz words in the market place. You will ask me what is 'Convenience', and how does it relate to processing of food. Observe some common examples around you. Pizzas, burgers, patties are some examples of convenient bakery take away foods in the market. They are convenient because you don't have to cook them simply buy them and eat them. Lets see more examples from fruits and vegetables. Have you observed that your subjiwala who sells green leafy vegetables such as palak, mustard and fenugreek now also keeps a small machine to cut them? Earlier this was never seen. Our mothers and grandmothers would spent hours together in cleaning and cutting such leafy vegetables. He now delivers convenience to you by cutting the leafy vegetables at this end. In cities, majority of women are working. She has less time for food preparation, and thus prefer to have precut vegetables. Why only working women even housewives like to have precut vegetables since it saves time and labour. Let us observe some more examples. Have you observed peeled and sliced pineapple rings and fleshy axils of pomegranate being sold in the busy market place? They are the most appropriate examples of convenience. You would often such things around busy office complexes. It is easier to eat an apple fruit than a pineapple which needs to be peeled, cored and sliced. What if the fruit is sold in form of sliced rings. It becomes more convenient to eat. Similar is the case with pomegranate, which needs to be peeled and fleshy arils, be removed from white placental tissue. Such convenience has become essential because of busy part and parcel of the urban lifestyle. Precut fruits and vegetables fulfil convenience and provides fresh like characters. With this background in mind, it will be easy for you to understand what minimal processing is. Now let us come to our main topic minimal processing.

Consumer and market trends

1. More health conscious
2. More working women in cities, less kitchen time, more eating out habits
3. More ageing and diverse population
4. Low fat, sodium and reduced calorie requirement
5. High requirement of Vitamin/mineral fortified food

Industry response to consumer trends

1. Increase in products with low fat and calories e.g. low fat butter, cheese spreads
2. Increase in availability of low calorie sweetner (asparatame, acesulfame) and diet colas
3. Introduction of foods with added health benefits (margarines, sport bar, fortified drinks) Choices in many categories such as dairy salad dress, frozen meals, snacks)
4. Increased availability of convenient foods breakfast bar, meal kits and ready to eat to meals, yoghurt cups, sprouted cereals and pulses, drinkable soup and frozen dinners.
5. Exploring newer methods of processing e.g. microwave and aseptic processing

Let us group these changes and see their consequences in a graphic form

Changes		Consequences
	→ Convenience →	More snacking, portability food service, relaxation foods, less cooking skill
More obesity, older consumers, health awareness (food/fitlink), safety concerns, alternative health solutions	→ Health →	More functional foods, natural/organic less junk foods
More older consumers, balanced health approach income polarization, change in leisure time	→ Indulgence →	More large portion sizes snacks, sweetness in flavouring, premium brands
More travel, immigration, media fragmentation, segment fragmentation, sophisticated consumers	→ Novelty →	More brand switching, fun foods, ethnic and brand foods

12.2 ADVANTAGES OF MINIMAL PROCESSING (MP)

In scientific language, MP is defined as these procedures such as washing, sorting, trimming, peeling, slicing or chopping that does not affect the freshness of the product. The result of such operations is a convenient fresh product that can be prepared and consumed in less time. Minimal processing is also called Light Processing. It may be defined in another form. Any fruit or vegetable or combination thereof that has been physically altered from its original form but remain in a fresh state. Since it includes pre-processing unit operations such as cutting, slicing and dicing, it is also called as 'Light Processing'.

Why has there been demand for such type of processing? What are its advantages over the other methods:

1. Consumers are increasingly demanding convenient, ready to use and ready to eat fruit and vegetables with a fresh like quality and containing only natural ingredients. They can easily go for meal preparation.

2. Delivers fresh like characteristics. Peeled, cut/shredded fruits and vegetables if delivered in time, offer fresh like characters.

3. Not only general consumers, the catering industry also wants to purchase fruits and vegetables that are sliced, grated or shredded. This is primarily for the reasons of expense, labour and hygiene.

4. Pre-packaging allows for more efficient portion control.

5. Solid waste disposal problems are reduced.

6. Demand on limited refrigerated storage spaces are reduced.

7. Supply of a variety of ready-to-eat items that exhibit excellent uniformity of quality and identity is available over many weeks.

Minimal processing is different from conventional processing

Conventional processing is different from minimal processing. While conventional food processing methods extend shelf-life of fruits and vegetables, minimal processing renders products highly perishable, requiring chilled storage to ensure a reasonable shelf-life. Preparation steps such as cutting, peeling renders them susceptible to wilting and desiccation. In conventional processing such as canning and freezing, many of these problems are prevented or controlled by heat inactivation or freezing or use of protective packaging materials or through application of food additives. Several chemicals are used for this purpose. Another important point of difference is that since no heat is applied to maintain fresh like characters, use of preservatives becomes mandatory here.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. The market place in food processing sector has changed in the last 25 years. Analyze the major factors.

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2. What has been the major consumer trend influencing the food processing industry?

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3. Name some convenient food products available in the market.

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4. Can you cite some examples of some minimally processed products available in the market?

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5. What is Minimal Processing?

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6. What are the alternate terms used for minimal processing?

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7. What are the main reasons for demand of MP produce?

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8. How is minimal processing different from conventional processing?

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12.3 PERISHABILITY OF MP

MP produce are highly perishable. They deteriorate fast because of physiological ageing, bio-chemical changes and microbial spoilage, which may result in the degradation of the colour, texture and flavour of the produce. Major deterioration factors are enzymes, ethylene and increased respiratory activity.

Enzymes

During peeling and grating operations, many cells are ruptured and intracellular products such as oxidizing enzymes are liberated. These enzymes are responsible for deterioration. The most important enzyme with regard to MP is polyphenol oxidase (PPO), which causes browning. Enzymatic browning requires presence of different components: oxygen, an oxidizing enzyme and a suitable substrate. To prevent browning, at-least one of these components must be removed from the system. Another important enzyme is lipo-oxidase which causes the formation of numerous bad smelling aldehydes and ketones.

Ethylene Production

Ethylene is a gas which is produced when fruits and vegetables respire. This gas is also called as the ripening harmone, and plays an important role in ripening of fruits. Cutting and peeling both release ethylene. It may be partially responsible for bringing about physiological changes in sliced fruit, such as softening.

Increase in respiration activity

Depending upon the produce and cutting grade and temperature, respiration activity of minimally processed increases 1.2-7.0 fold or even more. Increased respiration leads to anaerobic conditions and increased rate of spoilage.

12.4 FACTORS AFFECTING QUALITY

The main factors affecting the quality of minimally processed produce are harvesting operations, raw material, preparation procedures (trimming, cutting, peeling, shredding, processing conditions and Good manufacturing practices) In fact you can also study them under major unit operations of minimally processed produce.

Harvesting

Harvesting is a fundamental unit operation required for the production of minimally processed produce. Most of the raw material for fresh cut produce is cultivated under contracts that specify the cultivars and cultivation techniques in western countries (including sowing time, pesticide, fertilizer applications, and harvest conditions). Following points should also be borne in mind with regard to harvesting.

- Harvesting should be done preferably in the morning hours because of the cooler temperature.
- Pre-cooling to 1^{o}C, as soon as possible to extend potential shelf-life.
- Processing within 2 days of harvesting.

Raw material

Not all types of vegetables may be suitable for MP. Say, for example, onions, carrots and cabbage may be highly suitable for MP. Vegetables that can be washed and peeled easily are more suitable. Vegetables like tomato, calocasia and okra may not be best suited. Again, it is important to understand that not all varieties of a particular vegetable may be used for preparation. The correct choice of variety is particularly important in case of carrot, potato and onions. For example, carrot varieties that give the most juicy grated product cannot be used in the production of grated products that need to have a shelf-life of several day. Poor colour, flavour and microorganisms can create become problems if the selection of the variety is not proper. Main criteria in assessing suitability of cultivars to minimal processing are:

1. Processing yield (30-50%).
2. Low sensitivity to physiological disorders and microbial diseases.
3. Mechanical resistance to damage
4. Resistance to elevated carbon dioxide and/or low oxygen.
5. High sugar content because sugar may be responsible for energy stress.
6. Low respiration rate

Trimming

Trimming is an important unit operation sought after in vegetables especially in salad mixes. All unwanted parts of plants including outer green leaves are removed manually. This can be done using stainless steel knives, or ceramic blades. Cutting or bruising plant tissues with browning capability results in a brown discoloration. Using very sharp blades and chill storage can reduce browning.

Peeling, cutting and shredding

Some vegetables or fruits such as potatoes, carrots or apple require peeling. Peeling should be as gentle as possible. There are several methods of peeling, for example, hand peeling, steam, or lye peeling or industrial peeling using rotating carborundum drums. The ideal method is hand peeling using sharp knife. Peeling increases the respiration rate. Cutting and shredding must be performed with knives or blades that are as sharp as possible, these being made from stainless steel. Sharp blades are always better than blunt and dull blades. Blunt blades and knives impair the retention of quality because these rupture cells and release tissue fluid to a great extent. Mats and blades that are used in slicing operations can be disinfected with 1% hypochlorite solution. Cutting of vegetables should be preferably done under water. Because the internal liquid of injured cell is removed by water flow, browning is markedly compared to any commercial cutting technique.

Cleaning/washing/drying

Fruits and vegetables, after harvesting are covered with soil, mud or sand, they should be carefully cleaned before processing. Usually, a second washing is performed after peeling and/or cutting. For example, cabbage must be washed after shredding, however, carrot must be washed before grating. Washing after peeling and/or cutting removes microorganisms and tissue fluids, thus, reducing microbial growth and enzymatic oxidation during subsequent storage. Washing is done in ice-cold water (< 5^{o}C). Washing the produce in flowing or air-bubbling water is preferable to simplify dipping it in water. Both the microbiological and the sensory qualities of washing water must be good and its temperature is low, preferably < 5^{o}C. The recommended quantity of water that should be used is 5-10 l/kg of product before peeling and/or cutting and 3 l/kg after peeling and/or cutting. Preservatives can be used in the washing water to reduce microbial numbers and retard enzymatic activity, thereby improving both the shelf-life and sensory quality of the product. Chlorine is the most common preservative that is used in MP. Chlorine or citric acid (100-200 mg/l) is effective in the washing water before or after peeling to extend shelf-life. The effectiveness of chlorine can be enhanced by using a low pH, high temperature, pure water and correct contact time. The optimum chlorine concentration is 100 mg/l at a contact time of 12-13 seconds. Use of chlorine is banned in some European countries such as Belgium, Germany and Holland. The last step of washing operation is rinsing with tap water containing less than 0.5 ppm active chlorine. This step is used when chlorine is used at a concentration of higher than 1 ppm. Careful washing with water containing 100 mg chlorine/litre and subsequent rinsing improved the sensory shelf-life of minimally processed vegetables by several days, up to 7-8 days. Excessive free water on leaf surface leads to rapid bacterial spoilage.

Draining

Washing water should be gently removed from the product. Centrifugation seems to be the best method. It is important to choose the centrifugation time and rate carefully.

Dipping in anti-browning agents: Browning inhibition

Browning is the main quality problem in pre-peeled or cut fruits and vegetables. What happens to the apple slices and peeled potato, if you leave them open in air. You will find that after sometimes, the outer tissues start getting brown. This browning is basically a type of enzymatic browning, caused due to action of enzyme known as polyphenol oxidase (PPO). Oxidation of phenols in the presence of PPO causes these tissues to brown. Dipping the tissues in water or in salt water can reduce browning to some extent but cannot totally eliminate browning. The traditional preservative used to prevent browning are sulphites. Potassium metabisulphite is the most common preservative that has been used to control browning, however, its uses has some disadvantages. Recently, there have been reports regarding their harmful side effects for people with asthma. It is for this reason the US Food and Drug Administration (FDA) has partly restricted the use of sulphites in 1990, and since then there is increasing interest in substitutes for sulphites. In India, however, they continued to be used. Citric acid (CA) combined with ascorbic acid (AA) alone or in combination with potassium sorbate in case of potato, or Hexyl-resorcinol in the case of apple, seem to be promising alternatives for sulphites, particularly when hand peeling is used. Potatoes when heated for 5-20 min in a solution containing 1% ascorbic acid and 2% citric acid at 45-55^oC, cooled and then dipped for 5 min in a browning inhibitor solution containing 4% ascorbic acid. The combined treatment inhibits potato discolouration for 14 days at 4^oC, compared with 3-6 days with the browning inhibitor treatment alone.

12.5 PACKAGING AND STORAGE OF MINIMAL PROCESSED FRUITS AND VEGETABLES

12.5.1 Modified-Atmosphere Packaging and Edible Coatings

Packaging and storage is the last operation in the production of minimally processed fruits and vegetables. The most appropriate packaging method for precut raw fruit and vegetable is modified-atmosphere packaging (MAP). The basic principle in MAP is to create a modified atmosphere either passively or by using permeable packaging materials and by using a specified gas mixture with permeable packaging. The main purpose is to create an optimal gas balance inside the package, where the respiration activity of a product is as low as possible, but the levels of oxygen and carbon dioxide are not detrimental to the product. In general, the aim is to have a gas composition of 2-5% CO_2, 2-5% O_2 and the rest nitrogen. However, Optimal O_2-CO_2 atmosphere cannot be maintained by use of most of the films, especially when the produce has a very high level of respiration. One solution to this problem is to make microholes of a defined size and defined number in the matter to avoid anaerobiosis.

MAP is being used commercially for minimally processed lettuce, carrots and cabbage although current design is not sufficient to prevent the onset of fermentation under normal marketing conditions. In these cases, fermentation alters the flavour and quality of the product. This approach will not work for products such as broccoli that produce offensive off-flavour.

Packaging films such as combinations of ethylene vinyl acetate with oriented polypropylene and low density polyethylene have proved useful as these combinations have significantly high gas permeability. The shelf-life of shredded cabbage and grated carrots packed in these composites is 7-8 days at 5^oC. This is 2 days higher than oriented polypropylene which is generally used in the vegetable industry.

Edible coatings are another possible packaging method for extending the post-harvest storage life of minimally processed foods. Use of edible coatings is made from lipid resins, polysaccharides and proteins. In addition, plasticizers such as polyhydrin, alcohol, waxes and oils are added to improve flexibility and elongation of polymeric substances. Can you cite an example of edible coatings in your daily routine? The medicine capsules that you take when you fall sick, is a good example of an edible coating. Coatings serve dual functions. They serve as carrier of antimicrobial agents and retard loss of desirable flavour, volatiles and water vapour and restricts exchange of CO_2 and O_2 creating a modified atmosphere.

The packing room must be clean and refrigerated at 1-2^oC and must be separated from the washing section. Most of MP are packed in bags of polypropylene (25-40 um thick). Oriented polypropylene (OPP) is preferred to polyethylene mostly for its brightness, crispness and suitability for machine packing. The permanence of this film is suitable for packaging fresh cut endive and lettuce provided that distribution temperature does not exceed 10^oC. This film generates a modified atmosphere within bag that prevents necrosis of salad leaves. Salads (including lettuce), that are highly sensitive to oxidation are flushed with nitrogen so that residual oxygen within package range from 1-3%.

Temperature management after packaging is very essential, for minimizing the damaging effects of mechanical injury. Low temperature storage reduces metabolic reactions. It has a tremendous effect on respiration rates, and affects permeability of gases through packaging films and also slows down microbial growth. To ensure high quality products it is recommended that fresh cut products be kept at temperatures just above freezing. Usually 4-6^oC temperature is recommended for storage of fresh precut produce.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Why are MP perishable?

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2. What are main enzymes responsible for colour and flavour changes in MP?

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3. List some key requirements of minimally processed products for assuming quality.

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4. Shelf-life of MP strictly depends upon maintenance of low temperature during storage. Justify

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5. What is optimum dose for chlorination for minimal processed vegetables?

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6. What is referred to second washing in minimal processing? Why is it important?

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7. List some precautions with respect to washing of pre-cut produce.

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8. What type of packaging material is most appropriate for MP?

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9. Which of microorganisms can cause spoilage in fresh cut fruit & vegetables stored at low temperature?

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10. Identify some main criteria in assessing suitability of cultivars to MP.

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11. Name some vegetables that are highly suitable for MP.

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12. How can you improve the effectiveness of chlorine for washing?

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13. What precautions/points should be followed for peeling of fruit and vegetables for MP.

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14. Mention some strategies to prevent browning in MP fruit and vegetables.

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15. MAP is not recommended for which vegetable and why?

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12.5.2 Some General Processing Conditions, GMP's and Key Requirements of MP

Have you noticed that there was no mention of heating step in MP. It is for this reason that they must be handled and stored at refrigerated temperature at < 5°C to achieve a sufficient shelf-life and ensure microbiological safety. Shelf-life of minimally processed fruits and vegetables strictly depends upon maintenance of low temperature during storage. However, there are certain microorganisms which can also grow under low temperature conditions. Can you name any of such microorganisms? Pathogens such as *Listeria, Monocytogenes, Yersinia enterocolilica* and *Salmonella* can survive and even proliferate at low temperature. Such microorganisms are known as Psychrotrophic. So maintenance of hygienic conditions throughout the processing chain is the crux of MP. This becomes all the more important since no thermal heat processing is used. Following hygienic codes of practices or GMPs (Good manufacturing practices) are key requirements for MP and the best way to eliminate or keep away microorganisms.Lets see some points

The key requirements in the minimal processing of fruit and vegetables.

- Good quality raw materials (correct variety, correct cultivation, harvesting and storage conditions.
- Strict hygiene and good manufacturing practices, use of hazard analysis and critical control point principles.
- Low temperatures during processing.
- Careful cleaning and/or washing before and after peeling.
- Good quality water (sensory, microbiology, pH) for washing.
- Use of mild additives in washing water for disinfect ion for the prevention of browning.
- Gentle spin drying following washing.
- Gentle peeling.
- Gentle cutting, slicing and/or shredding.
- Correct packaging materials and packaging methods.
- Correct temperature and humidity during distribution and retailing.

We have seen that MP are extremely perishable. In order to extend their shelf-life we should follow certain guidelines which are aimed at reducing biological, physical and chemical hazards. Guidelines propose conditions under which raw materials are grown as well as processing and distribution guidelines. Let us see some of these guidelines.

Forward only movement

Generally raw material is considered to be unclean product. I think by this time you know why is this so? Raw material is unclean because it may be loaded with surface microorganisms which if not cleaned can cause contamination. Keeping this in mind, raw material should be separated from the clean finished product. This requires that there should be no crossing over in the processing line between the raw material and clean products.

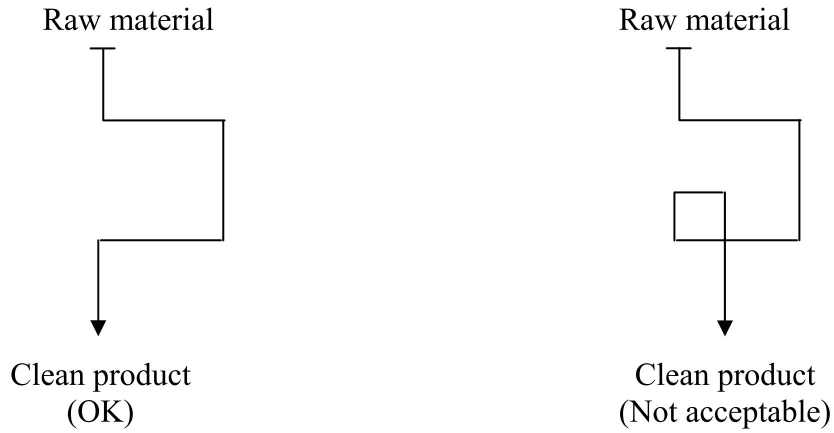

Figure 12.1: Principle of forward-only movement

Separation of the trimming room, washing room and the packing room

In order to prevent cross contamination, the different processing rooms must be delimited by walls in order to progressively increase cleanliness from the trimming room to the packaging section

Trimming room →	Washing disinfecting rinsing →	Packaging

Figure 12.2: Segmentation of processing line

Temperature control

Fresh-packed products must be immediately stored at 4°C and maintained at 0-4°C until delivered to consumers.

Air flow	→	→	Positive Pressure	
	12°C	WASHING	4°C	
Raw material	Trimming pre-washing		Packing	Carton expedition

Figure 12.3: Temperature gradient and air flow in the processing unit

The following are therefore recommended:

1. Limit exposure to temperatures above 10°C

2. Refrigerate the product at 0-2^{o}C before packing in order to be at the right temperature during the operation.
3. Maintain this temperature during storage.

The temperature gradient and flow of products run counter-currently. Temperature in the trimming and disinfecting rooms must not exceed 12^{o}C and must not exceed 4^{o}C in the packing room and ware house.

Air Flow

Ventilation systems are designed to maintain the required temperature and prevent both condensation and circulation of dust. The air current must flow from the packing to the trimming room.

Wastes

Waste materials are evacuated from the facility to avoid any cross-contamination (Figure 12.4). The equipment and machinery used for non-edible material and waste must be clearly identified and never used for edible product. Moreover, they should be easy to wash and sanitized.

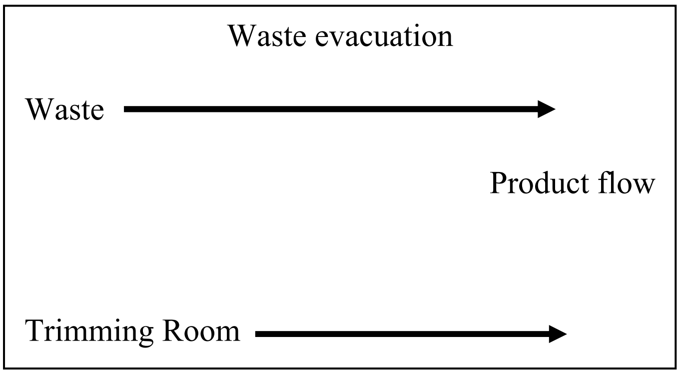

Figure 12.4: Waste disposal

Cleaning, equipment, material and utensil

Washing should be performed by any method of combination of methods involving mechanical action (scrubbing, brushing, water, jet spraying) or chemical cleaning (acidic or alkali detergent). A detergent or disinfecting detergent should be applied so as to permit the elimination of dirt and bacterial biofilms. Efficient rinsing with potable water should eliminate the detached particles and detergent residues.

Sanitation

Product safety is the very critical sanitation issue of the minimal processing plant. Processing of the product and employee practices are some of the factors influencing the plant sanitation. These include, sanitary layout of processing facility, processing rooms with positive airflow and sanitary design of processing equipment. Washing the premises and machines with steam or chemicals. Good manufacturing practices (GMP's) and hygiene are pre-requisites to ensuring quality in minimally processed foods.

Hygenic procedures for operators

Personnel should know the hygienic procedure (International Code of Practices, general principles of food hygiene) and wear protective clothing and foot-wear specific to the area.

Quality assurance programs

An effective quality assurance system throughout the handling steps between harvest and retail display is required to provide a consistent good quality supply of fresh-cut fruits and vegetables to the consumers and to protect the reputation of a given marketing label. Quality assurance starts in the field with selection of proper time to harvest for maximum quality. Exposure of commodity to temperatures, relative humidities, and/or concentration of oxygen and ethylene outside its optimum ranges accelerates loss of quality. The loss of flavour and nutritional quality occurs at the faster rate then appearance factors. That's why quality assurance programs should be based on quality attributes and not on appearance factor as is often the case.

Following is a list of handling steps and associated quality assurance functions:

1. Training workers on proper maturity and quality selection, careful handling, and produce protection from sun exposure during harvesting operations

2. Checking product maturity, quality, and temperature upon arrival at the processing plant

3. Implementing an effective sanitation program to reduce microbial load

4. Checking packaging materials and shipping containers to ensure they meet specifications

5. Training workers on proper processing and packaging operations

6. Inspecting a random sample of the packed product to ensure that it meets grade specification

7. Monitoring product temperature to assure completion of the cooling process before shipment

8. Inspecting all transport vehicles before loading for functionality and cleanliness

9. Training workers on proper loading and placement of temperature-recording devices in each load

10. Keeping records of all shipments as part of the "trace-back" system

11. Checking product quality upon receipt and moving it quickly to the appropriate storage area

12. Shipping product from distribution centre to retain markets without delay and on a first-in/first-out basis unless its condition necessitates a different order

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What is referred to 'Forward only' movement in MP?

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2. Name some inhibitors that can inhibit the activity of PPO.

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12.6 LET US SUM UP

A characteristics feature of minimal processing is an integrated approach where raw materials is an integrated approach, where raw materials, handling, processing, packaging and distribution must all be properly considered to make shelf-life extension possible. New cultivars need to be selected and created or hybrids adapted to meet the specific requirements of minimal processing**.** The equipment used in unit operations, such as peeling, and shredding, needs further developments so it can process produce more gently. Further for maintaining quality in minimal processing requires anti-browning agents such as acidulants (citric acid), reducing agents like ascorbic acid. All these combined with proper packaging material and low temperature will result into a shelf stable product.

12.7 KEY WORDS

Minimal processing : is defined as these procedures such as washing, sorting, trimming, peeling, slicing or chopping that does not affect the freshness of the product.

Good manufacturing practices : refers to hygienic code of practice which are to be followed to maintain quality in food processing unit.

Modified atmosphere packaging : It involves modifying the atmosphere around the food product inside the wrapper. This allows chemical, enzymatic or microbiological reactions to be controlled and therefore reduces or eliminates the main processes of deterioration in the product

12.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Availability of more processed fruits and vegetables.
   - Innovative packaging.
   - Consumer demands (demand for convenient and quality products, dual incomes).
   - Taste preferences.
   - Technological advances in food processing.

2. Your answer should include the following points:

   - Demand for convenient and high quality processed products.
   - More working women in cities and less time for kitchen

3. Your answer should include the following points:

   - Bakery goods, pizzas, burgers, French fries, confectionary items.
   - Fruit and vegetable juices tetra packs take away colas, instant juice concentrates.
   - Frozen foods, frozen vegetables, peas, beans, cauliflowers etc.
   - Sauces ketchups, concentrate purees, yoghurts, curds etc.

4. Your answer should include the following points:

   - Pre-cut salads and fruit slices.
   - Sprouted pulses.
     Shelled peas.

5. Minimal processing is defined as procedures such as washing, sorting, trimming, peeling, slicing/chopping that does not affect the freshness of product.

6. MP is also known as

   - Light processing
   - Precut produce

7. Need for fresh like characters.

   - Need for convenience.
   - Need for quality.
     Fresh produce gives health

8. MP is different from conventional processing in following manner:

   - No heat used.
   - Product has limited shelf life (4-21 days).
   - Chilled/refrigerated storage is must during transportation & retailing.
   - Produce is more close to fresh ones.

Check Your Progress Exercise 2

1. MP are perishable because

   - Cutting/shredding renders produce susceptible to desiccation/wilting, biochemical and microbial spoilage.
   - Fast degradation of colour, flavour and texture because of ethylene liberation, increased respiratory activity and enzymatic changes.

2. Main enzymes responsible for colour and flavour changes are:

   - Polyphenol oxidase causes browning.
   - Lipo-oxidase causes bad smelling odours

3. Your answer should include the following points:

   Key requirements for minimal processing

   - Good quality raw material.
   - Strict hygiene and use of GMPs.
   - Low temperature during processing.
   - Good quality water.
   - Gentle spin drying.
   - Gentle peeling, slicing and shredding.
   - Correct packaging material and packaging methods.

4. Low temperature lowers down metabolic activities and helps to extend shelf-life.

   - Delays microbial spoilage.
   - Name some microorganisms.
   - Salmonella sp.
   - Listeria sp.
   - Monocytogenes sp.
   - Yersinea sp.

5. The optimum chlorine concentration is 100 mg/l at a contact time of 12-13 seconds.

6. Your answer should include the following points:

   Second washing is performed after peeling/cutting/shredding/dicing. It is done in ice-cold water (> 5^{o}C). It is important because it:

   - Removes tissue fluids and microorganisms.
   - Reduces enzymatic oxidation.
   - Low temperature seals the cut/damaged surfaces.
   - Washing before peeling and after cutting/shredding/dicing.

- Second washing in ice-cold water (> 5°C).
- Use of preservatives in washing water containing 100 mg chlorine/l.
- Rinsing with tap water after washing.

7. Your answer should include the following points:

- Washing before peeling and after cutting/shredding/dicing.
- Second washing in ice-cold water (> 5°C).
- Use of preservatives in washing water containing 100 mg chlorine/l.
- Rinsing with tap water after washing.

8. Your answer should include the following points:

- Oriented polypropylene.
- LDP – Low density polyethylene.
- Ethylene vinyl acetate.

9. Main Micro-organisms are:

- L. monocytogenes.
- Acromonas hydrophila

10. Your answer should include the following points:

Main criteria in assessing suitability of cultivars to MP.

- Processing yield (30-50%).
- Mechanical resistance to damage.
- Resistance to elevated CO_2 or low oxygen.
- Low respiration rate.

11. Your answer should include the following points:

- Onions
- Carrots
- Cabbage

12. Your answer should include the following points:

- Low pH
- High temperature
- Correct contact

13. Your answer should include the following points:

- Gentle rather than harsh peeling
- Peeling with sharp knives
- Disinfection with 1% hypochlorite solution
- Cutting or peeling done under water

14. Your answer should include the following points:

- Placing the tissues in water immediately after cutting
- Use of potassium metasulphite
- Citric acid combined with ascorbic acid alone or in combination with potassium sorbate.

15. Your answer should include the following points:

    MAP is not recommended for:

    - Broccoli
    - Cauliflower
    - Onions

    Because they emanate offensive odours during storage.

Check Your Progress Exercise 3

1. *Forward only movement*

   Forward only movement refers to complete separation of raw material from clean finished product. This requires that there is no crossing over in the processing line between raw material and clean products.

2. Your answer should include the following points:

   - Sodium chloride
   - 4-Hexyl resorcinol
   - Ascorbic acid
   - Sporix and cyclodextrins.

12.9 SOME USEFUL BOOKS

1. Lamikanra, Olsuola (2002) Fresh Cut Fruit and Vegetable Science, CRC Press.

2. Ohlsso, Thomas and Bengtsson, Nils (2004) Minimal Processing Technologies in Food Industry CHIPS.

3. Pulle, Mervyn (2004) Food Processing Insights into Food Manufacturing Food Technology, Part 4, Part 4KBS publishers.

4. Singh, R.P. and Oliveira, F.A.R (1994) Minimal Processing of Foods and Process Optimization, CRC.

5. Wiley, R.C. (1994) Minimally Processed Refrigerated Processed Fruits and Vegetables, CRC.

UNIT 13 PROCESSING BY HEAT APPLICATION

Structure

13.0 OBJECTIVES

After reading this unit, you should be able to:

- define types of heat applications;
- describe the role of heat application during processing and product preparation;
- state the effect of heat application on quality of food, microorganisms and enzymes; and
- discuss the effect of heat in combination with time, temperature, pH or acidity.

13.1 INTRODUCTION

Fruits and vegetables are living entities and highly perishable horticulture produce. Enzymes and microorganisms can easily spoil these commodities. In order to keep fruits and vegetables for a longer period, they are protected by several means. Heat application is one of the most important methods of preservation of fruits and vegetables. The main purpose of processing of fruits and vegetables by application of heat is to inactivate enzymes and killing of microorganisms. Heat can be applied in different forms such as blanching, pasteurization and sterilization. Heat application influences the texture and composition of fruits and vegetables, and microorganisms and enzymes. Heat application plays a great role during various unit operations of processing of fruits and vegetables viz., peeling, preparation of juice and pulp; syrup and brine, during blanching, exhausting, pasteurization or sterilization. There are certain factors like time, temperature; pH and acidity in combination with heat application will affect the quality of the processed products. There are several types of processed products, generally preserved by heat application such as jam, jelly, juices, sauces, candies, canned and bottled products etc. Heat processing has advantages such as to improve eating quality and availability of some nutrients and a simple control of processing conditions.

13.2 EFFECT OF HEAT ON TEXTURE AND COMPOSITION

Carbohydrates, proteins, fats, vitamins, minerals and fibre are the major dietary constituents of fresh vegetables in addition to a large quantity of water. Fruits are held in high public regard as sources of wholesome food and are valued for their taste, aroma and texture. Fresh fruits appeal virtually to all the senses, smell, taste, touch, sight and even sound as when one bites into crunchy apple. Vitamins and minerals are the major contributions of fruits to the human diet. Although some fruits are also considered good energy sources and some may contribute notable amount of fat (e.g. Avocados and nuts), sugar (e.g. Dates and figs) and proteins (e.g. tucuma). Fruits may play an important role in the diet by supplying fibre.

Heat processing is one of the most important methods for extending the storage life of fruit and vegetable products. Because of this extended life, the processed products are made available throughout the year. This has increased the availability of nutrients to the consumer. However, heat processing also has a detrimental effect on nutrients since there is thermal degradation of nutrients. Therefore, heat processing makes it possible to extend and increase availability of a food product to the consumer, but the food product may have a lower nutrient content compared to the fresh food product. This is a great challenge to the food processing industry is to minimize the loss of nutrients during thermal processing.

Heat processes are used in terms of blanching, pasteurization and sterilization. The primary objective of heat processing is to increase the palatability of the food and to increase the storage life of food product besides minimizing food-borne diseases. For example, the cooking, which includes roasting, boiling, frying etc. The heat processes viz. blanching, pasteurization and sterilization has already dealt in Para 2.5 and 2.6 in a greater details, here we are discussing their effect on texture and composition of fruits and vegetables.

Heat processing generally includes the terms blanching, pasteurization and sterilization and their principal purpose is given here.

Blanching is a heat process frequently applied to fruit and vegetables prior to freezing, drying or canning. The objective of the blanching process depends on the subsequent treatment of the foodstuffs. The adequacy of the blanching operation is enzyme inactivation. Generally, if enzymes are inactivated, the heat treatment was sufficient to accomplish the objectives of blanching prior to canning.

Pasteurization is a heat process meant to inactivate part, but not all, of the vegetative microorganisms present in the food product. Since the food is not sterile, the pasteurization must also be used in conjunction with other preservation techniques like fermentation, refrigeration, and maintenance of anaerobic conditions.

Sterile is a term, which used to a condition in which no viable microorganisms are present. A viable organism being one that is able to reproduce under conditions optimum for its growth. Sterilization is a term used to apply to a heat process that produces a sterile condition in food product. Some microorganisms and their spores are extremely heat resistant and cannot be destroyed completely. Severe heat treatment can only make the food sterile, but it will influence the organoleptic and nutritive value of food. Therefore, the sterilization process is also used in conjunction with other preservation techniques, such as packaging and control of storage temperature. Thus, the remaining dormant microorganisms or their spores will not grow in the environment of the food under the storage. Foods that have been thermally processed and meet this requirement are said to be "commercially sterile".

Heat processing may change not only the chemical composition of the food but also its structure by softening tissues, releasing or tying up moisture, destroying or forming colloidal suspensions, gels or emulsions. Protein may become denatured and therefore more available to some organisms than it was in the native state. Starch or protein may become gelated, releasing moisture and becoming more easily decomposed. For the same reasons, cooked food usually is more easily decomposed than the original fresh food.

Preservation is a convenient method of storing fruit for use in periods when the fresh products are not available. The characteristics of fruit are usually altered to such an extent during processing that the processed products do not necessarily resemble the fresh products. If processed and stored properly, the nutritive value of these processed fruit is comparable to that of the fresh products.

The thermal processes viz. blanching, pasteurization and commercial sterilization have to be optimized for nutrient retention, given in the box below:

Process	**Method of optimization**
Blanching	Thermal losses, leaching losses, oxidative degradation, damage to product
Pasteurization	HTST if heat resistant enzymes are not present
Commercial	Convection – heating foods and aseptic processing.
Sterilization	HTST until heat-resistant enzymes become important
Conduction	heating foods; not necessarily HTST; difficult but not impossible calculation.

Effect of blanching on nutrients

The effect of blanching on food nutrients is generally considered based on thermal, leaching and oxidative losses. Blanching is done either by dipping in hot water or exposing to steam. In water blanching the loss of water –soluble vitamins increases with contact time, and fat – soluble vitamins are relatively unaffected. Steam Blanching results in greater retention of water – soluble nutrients than water blanching. There is a slight improvement in ascorbic acid retention with IQB (individual quick blanch) as compared to conventional steam blanching. In conclusion, blanching can significantly reduce the nutrient content of foods. The extent of losses of nutrient is dependent on the blanching method and the product.

Effect of pasteurization on nutrients

The foods having a low pH (mostly below 4.5) are generally pasteurized. Some food products, which receive pasteurization, are summarized in the box given below:

Food Products preserved by Pasteurization treatments

Sl. No.	**Product Pasteurized**	**Temperature (^oC)**
1.	Carbonated Beverages	60-65
2.	Non Alcoholic fruit drinks	65-70
3.	Dill Pickles, Carbonated fruit juices	70-75
4.	Apple juice (Holding process) grape juice, raspberries, strawberries in syrups in cans or jars	75-80
5.	Processed and pickled vegetables, wine (U.S.), desiccated coconut	80-85
6.	Apple juice (flash process), canned olives, citrus juices, peeled tomatoes (pH 4.1)	85-90
7.	Tomato puree, citrus juices (flash process) tomato juice, peeled tomatoes (pH 4.5), Jam	90-95
8.	Wine (flash process), fruit puree, fruit juices, canned fruits (internal can temp.)	95-100

Source: Shapton et al. (1971)

Since most of the heat – labile nutrients are relatively stable in acid conditions; nutrients losses in those products are relatively minor. Although thermal losses during pasteurization may be small, oxidative losses can be high.

We have already discussed that HT ST (High Temperature Short Time) process results in greater nutrients retention for those nutrients affected by the pasteurization process. They are primarily thiamin, vitamin C and vitamin B 12. The nutrients that are more sensitive to high temperature are generally the same ones that are of concern during storage. It would be reasonable that the lower the storage temperature, the slower the rate of nutrient degradation.

Effect of commercial sterilization

The destruction of nutrients the thermal process is dependent on i) time-temperature treatment used as the basis of the process and ii) rate of heat transfer into the product. The commercial developments have focused primarily on increasing the rate of heat transfer into the product. Hence, agitated retorts such as the orbitort, steritort, flame sterilizer and hydrostatic cooker have been developed.

In addition to increasing the rate of heat transfer, however, there also has been a gradual shift to higher processing temperature. This results in adaptation of HTST process for greater nutrient retention in those products heating primarily by convection. It has been observed (Ammerman 1957) that retention of vitamin C in tomato juice is improved when processing is conducted at a HTST condition.

The HTST process is particularly adaptable to aseptic processing. In this system, processing temperatures in excess of 149^{o}C are used for very short periods i.e. order of seconds. Under these conditions nutrient retention may be greatly enhanced. HTST aseptic canning also results in a significant improvement in organoleptic qualities i.e. colour, taste and aroma. In an evaluation of HTST aseptic processing, it was found that thiamin retention was significantly greater in HTST products than in conventionally canned and retorted products. Based on existing literature available, nutrient losses range from 0 to 91 percent, depending on the nutrient and product.

It is a misconception to think that commercially sterile products remain unchanged during storage. This is not the truth. Organoleptic and nutrient changes do occur during storage, the extent of the changes being dependent on the time and temperature of storage. It has been observed that low temperature storage results in an improvement in nutrient retention.

In conclusion, it is evident that there is a significant loss of nutrients during canning and that these losses increase during storage. Altering heat processing and storage conditions to maximize nutrient retention is an important and necessary consideration for the fruit and vegetable processing industry.

13.3 EFFECT OF HEAT ON MICROORGANISMS AND ENZYMES

Generally the food spoilage takes place at any temperature between –5^{o} and 70^{o}C. Since microorganisms differ so widely in their optimal, minimal and maximal temperature for growth, it is obvious that the temperature at which a food is held will have a great influence on the kind, rate and amount of microbial induced change that will take place. Even a small change in temperature may favour an entirely different kind of organism and result in different type of spoilage. For example, moulds and yeasts generally do not grow well above 35 to 37°C, hence not important in foods held at high temperatures. But moulds and yeasts grow well at ordinary room temperatures and many of them grow fairly well at low temperatures. Most bacteria grow best at ordinary temperatures. Some (thermopiles) grow well at high temperatures and others (psychrotopes) at chilling temperatures. The heat, which kills microorganisms and inactivate enzymes is supposed to be denaturation of the proteins. The heat treatment varies depending upon the different factors such as kind of organism, its state and the environment during heating. Depending upon the heat treatment employed, only part of the vegetative cells, most or all of them may be killed. There are known certain terms of heat treatment given below:

Heat Processing – Use of high temperature to destroy enzymes and microorganisms that could reduce quality and /or safety of food.

UHT – A very severe heat treatment, very short in time.

Pasteurization – A mild heat treatment used primarily to destroy pathogenic organisms but it also destroys enzymes and reduces microbial load. Requires an addition preservation method to extend shelf life (for example – refrigeration, drying).

Commercial sterilization – A severe heat treatment that destroys pathogenic and many microorganisms that could spoil food. Extends shelf life, room temperature stable.

Sterilization – A very severe heat treatment that destroys all microorganisms.

Details of these heat treatments can be seen in other Para of this unit.

Factors affecting heat resistance

There are certain factors, which are known to affect the heat resistance of cells or spores of microorganisms. This point must be kept in mind when microorganisms are compared and when heat treatments for destruction of an organism are considered. The main known factors are listed below:

1. The temperature – time relationship – The time for killing cells or spores under a given environment decreases as the temperature is increased.

2. Initial Concentration of Spores – the more the spores present, the greater is the heat treatment required to kill all of them.

3. Environment of Vegetative spores –

   i) *Medium of growth:* Nutrients in the growth medium influences the heat resistance. The better the medium for growth, the more resistant the spores cell.

   ii) *Temperature of incubation*: In general, resistance increases as the incubation temperature is raised toward the optimum for the organisms.

   iii) *State of growth and age:* Very young immature spores are less resistant than mature ones.

   iv) *Desiccation:* Certain spores are harder to kill by heat than those kept moist.

4. Composition of substrate also influences the thermal death time of the microorganisms.

   i) Moist heat is a much more effective killing agent than dry heat.

   ii) *pH:* In general microbial cells or spores are most heat – resistant in a substrate near neutrality. (See more details in 2.7 Para)

   iii) *Other constituents:* Common salt and sugar also protect some organisms or spores. The colloidal materials, especially proteins and fats, are protective against heat.

Heat resistance of microorganisms

The heat resistance of microorganisms usually is expresses in terms of their thermal death time. The thermal death time (TDT), which is defined as the time it takes at a certain temperature to kill a stated number of organisms (or spores) under specified conditions.

Most of the yeasts, moulds and their spores are killed by moist heat at 60°C, but some species are considerably more heat resistance, but may not survive 100°C. The bacterial vegetative cells are easily killed at 80-90°C. But resistance of bacterial spores at 100°C may vary from less than 1 minute to over 20 Hours.

Heat resistance of enzymes

The most food enzymes are destroyed at 80°C, some may with stand higher temperatures, especially if high temperature – short –time heating is employed. Generally the effect of heat is intended for preservations of food i.e. to kill bacteria and inactivate enzymes. For example, the pasteurization of milk, fruit juice and beverages and the sterilization of canned foods. The main aim is to deliver the required microbial kill with as little damage to the structure and consumption of the food products as possible.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Named constituents of fruits and vegetables.

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2. What is the primary objective of heat processing?

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3. What are the methods of optimization of heat process?

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4. Define different terms of heat treatments.

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5. List the factors affecting heat resistance.

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13.4 ROLE OF HEAT APPLICATION – PEELING, JUICE PROCESSING, SYRUP/BRINE PREPARATION & FILLING

13.4.1 Use of Heat in Peeling of Fruits and Vegetables

Generally fruits and vegetables are peeled by hand, mechanical means, use of heat and lye solution. Heat in various forms is applied in last two methods of peeling. Heat is generally used in the form of boiling water, steam, roasting by a direct gas flame and heating in steam under pressure.

Peaches, tomatoes, beetroots are either immersed in boiling water or exposed to live steam until it loosen skin or cracked or peel is separated from the flesh easily, and then cool by spraying or immersion in cold water. The loose/ cracked or separated skin is easily slipped from the fruit by hand or by spraying water.

Sweet potatoes are steamed under pressure to soften the skin and are peeled by hand. Sometimes peeling of carrots, beets, potatoes and apples and some other vegetables can be done by heating under pressure to a very high temperature for a few seconds then releasing the pressure. This method of peeling can be a continuous or batch type process.

Pimientos and onions are flame-peeled in a continuous natural gas-heated chamber at very high temperature (1568°C). Then they are washed in sprays of water. Uniform size of the produce gives better results.

Heat is also used during lye peeling. It makes the lye solution more effective than cold lye. Lye is a solution of alkali such as sodium hydroxide. Its strength and time of immersion of the commodities depends upon type and nature of fruits and vegetables and thickness of their skin. Lye peeling is used on peaches, sweet potatoes, apricots and carrots. Sometimes the sodium carbonate-sodium hydroxide mixture is also used, is called canners alkali. The lye solution having 1.5 to 2 percent sodium hydroxide is used for peeling of fruits. For vegetables 10 to 15 percent sodium hydroxide solution is used. The time of immersion in lye solution for fruits varies from ½ to 2 minutes and 6-8 minutes for vegetables. The boiling dilute lye solution causes the separation of the outer skin of the fruits from the flesh. In case of sweet potatoes the action of lye solution is upon the cutin.

13.4.2 Use of Heat in Juice and Pulp Processing

Use of heat application helps in clarification and preservation of fruit juices and beverages. Fruit juices after pasteurization will become clear during storage. The length of storage required depends upon the type of juice and other conditions. For example the pomegranate juice will become clear within twenty four hours, after pasteurization where as grape juice requires several months for setting solids and it can be enhanced by refrigerated low temperatures.

The heat treatment is used to pasteurize the fruit juices and it means the destruction of all microorganisms capable of increasing in the juice of causing spoilage. It doesn't kill the spore forming bacteria such as *Bacillus subtilis* and *Bacillus mesentericus* but these spore bearing bacteria cannot grow in acid fruit juices. However, pasteurization should be done at such a temperature and for such a time that yeast and moulds are destroyed. For example yeast is killed in a few minutes by heating juice at 60-66°C. But resistant mould spores require a temperature of 80^{0}C for 20 minutes; however, carbonated juices can be pasteurized safely at 66°C. Thus, we can conclude that the fruit juices must be pasteurized at lower temperature (71-74°C).

The presence of carbon dioxide generally does not reduce the death temperature of fruit juice microorganisms such as yeast, mould spores, and bacteria. But it prevents the growth of surviving mould spores. However, it has been observed that carbonated and heavily inoculated fruit juice heated for 30 minutes at 65°C, which prevents subsequent development of mould spores.

The bulk juices are pasteurized either as continuous or batch type process. The continuous pasteurization is done in a tubular or plate type heat exchangers. Hot water or steam is used as heating medium. The batch type pasteurization is done in steam-jacketed kettle or in a tank equipped with steam coils. In these vessels, the juice is placed and heated to the desired temperature. This system has some disadvantages such as the small portion of juice may be over heated or exposed to air and cause oxidation during pasteurization and injury to colour and flavour on prolong heating.

Heating can also be done by electricity. The fruit juices are passed between carbon electrodes. The juice is heated instantaneously to the desired temperature when ordinary alternating current (110 Volts 60cycle) is passed in the electrodes. Heat is generated by passage of current against the resistance of juice, without heating the electrodes.

The fruit juices are also preserved by flash pasteurization and cooling. The prolong heating results in considerable injury to the flavour and colour of the products. Hence, the fruit juices are heated at higher temperatures and rapidly cooled and then under aseptic conditions filled into sterile containers such as bottles and sealing by sterile cork or caps. Great care must be taken to avoid the infecting juice with mould or yeast. For example the juice is heated to about 82 to 90°C for a few seconds only, the juice suffers very less injury to colour or flavour. In some instances the citrus, apple or tomato juice is flash pasteurized momentarily at 116°C or higher, but cooled to 98°C (tomato juice) and 88°C to other juices before filling into the container. This treatment will inactivate enzymes also. Now a day's pasteurization is generally done by "hot-fill-hold-cool" method. In this method the hot sterile bottles or cans usually filled hot directly from bulk or continuous pasteurizer, sealed and given no further heating but cooled in the air and water, respectively.

Heat should also be used to sterilize bottles, cans, and bottle caps otherwise they may cause infection in bottled beverages.

13.4.3 Syrup/Brine Preparation and Filling

The syrups are added to fruits and brines are added to vegetables during canning. These additives improve the flavour; fill the spaces between the pieces of canned fruits and vegetables and aid in the transfer of heat during the processing.

For making syrup, cane sugar, liquid glucose or invert sugar is used but usually cane sugar is employed. The sugar is dissolved in small quantity of water to yield heavy syrup (60-65^{0}Brix). The cane sugar and water are heated together until a clear syrup is obtained. Heat treatment is provided through steam. Tanks with steam heated coils or steam jacketed kettle is used for the preparation of the syrup. Sugar syrup is clarified by passing through cloth. Then it is diluted to the desired degree Brix depending on the nature and grades of the fruit. Here the heating helps in dissolving sugar in the water and quick filtration before it is cooled. Hot syrup is filled into cans containing fruit pieces, which helps in reducing time of exhausting.

Dilute brines of 1 to 2 percent common salt are used during canning of vegetables. Salt used for canning should be at least 99 % sodium chloride ($NaCl$) and lower purity less than 98 % should not be used. Salt is dissolved in water by heating, after proper filtration is filled into the cans containing prepared vegetables before exhausting. Hot brine is used for filling into the cans.

13.5 BLANCHING AND EXHAUSTING

13.5.1 Blanching

Blanching is a unit operation applied to fruits and vegetables prior to canning, drying or freezing. Blanching is a mild type of heat processing. It involves heating food to preset temperature for preset time. It is usually done in water or steam at a temperature less than 100°C. Prepared fruits and vegetables is kept in hot water or exposed to steam and then cool rapidly to ambient temperature.

Blanching is used to destroy microorganism and enzymatic activity in fruits and vegetables. Blanching caused inactivation of enzymes in canning, freezing and dehydration, because freezing and dehydration are insufficient to inactivate enzymes. Sometimes canning process may allow sufficient time for enzymatic activity. And under blanching may increase the enzymatic activity. There are four types of enzymes such as lipoxygenase, polyphenololase, polygalacturonase and chlorophyllase, which causes loss of quality in fruits and vegetables, must be inactivated. The enzymes such as catalase and peroxidase are heat resistant, which need appropriate time and temperature to inactivate them.

Blanching also reduces the number of microorganisms. Blanching of fruits and vegetables in steam has the advantages such as less loss of water-soluble constituents, less volume of waste, easy to clean and sterilize. But it has some disadvantages i.e. higher capital costs, uneven blanching, and low efficiency. Generally hot water blanchers are used because of lower capital costs and better energy efficiency. But it has some disadvantages like loss of water-soluble constituents, risk of contamination and higher cost of water and disposal of effluent than steam blanchers.

Blanching of green leafy vegetables especially spinach at boiling point causes loss of green colour but lower temperature (77°C), it retains the natural green colour, even when heated at higher temperature (121°C) during sterilization. At lower temperature time the enzyme chlorophyllage remains active for little time and convert chlorophyll to a phyllin, which retain green colour.

13.5.2 Exhausting

Exhausting is a mild type of heat processing. It is one of the unit operations involved during canning of foods. Exhausting, generally remove air and gases from cans. It can be done either by application of heat. In this method, the cans are passed through a tank of hot water or exhaust box under steam. The temperature of water is generally ranged between 82^0C to 100^0C and the center of the can should reach a temperature of about 79^0C. The time of exhausting varies from 6 to 10 minutes, depending upon the nature of the commodities. Generally, exhausting of the cans is preferred at lower temperature for a longer time to ensure to uniform heating of the contents, without softening of the produce. Exhausting at high temperature should be avoided, otherwise it will be formed more volume of water vapour, which may produce greater vacuum in the can.

Exhausting help in avoiding the corrosion of the tin plate and pin holing during storage, minimizing discolouration by preventing oxidation, better retention of vitamin C, prevents bulging of cans when stored at high altitude. It also helps in reducing chemical reaction between containers and food and prevents development of expressive pressure and strain during sterilization of cans.

13.6 PASTEURISATION AND STERILISATION

13.6.1 Pasteurization

Pasteurization is a mild type of heat processing. In this method, the heat treatment is performed below 100°C, which kills some selective but not all of the microorganisms present. Heating is done in form of hot water, steam, dry heat or electric currents. The food products are cooled rapidly to ambient temperature after heat treatment.

The main function of pasteurization is to inactivate enzymes, kill non-spore forming bacteria, yeasts and moulds. Pasteurisation is used in combination of other preservation methods such as fermentation (pickles), refrigeration and anaerobic conditions as the food products are not sterile. Pasteurization is generally used in fruit juices, where the environment is not suited for the growth of spoilage causing microorganisms.

The severity of pasteurisation depends on pH of the food products. In low acid ($pH>4.5$) foods, the destruction of pathogenic bacteria, whereas in high acid foods ($pH<4.5$), the destruction of spoilage microorganisms and inactivation of enzymes are essentially the requirement.

Heating to 100°C mostly preserves the fruit juices or slightly below for a sufficient time to kill spoilage microorganisms are called pasteurization. Generally, the fruit juice is hermetically sealed in cans or glass bottles before being pasteurized. The juice would not spoil as long as the cans or bottles remain sealed against the entry of spoilage microorganisms from outside. Some spores and spore forming bacteria like *Bacillus subtilis* and *Bacillus mesentericus* can survive the process. But these organisms are highly sensitive to acid products and cannot grow in acid fruit juices and beverages. Generally, the fruit juices are pasteurized at about 85^{0}C for 25 to 30 minutes depending upon the nature of the juice and the size of the containers. In this process most of the bacteria, mould, spores and yeasts are readily killed.

Fruit juices are pasteurized by two methods. First by heating the juice at a low temperature for a long period, and secondly by heating the juice at high temperature for a short time (HTST). Pasteurisation is governed by the temperature and its types & methodology. For example under 'Holding' pasteurisation also called Bottle method, the prepared and finished juice is filled into glass bottles leaving proper head space. The bottles are then sealed airtight and pasteurized. The headspace is left in the bottle for the expansion of the juice during heating. In over-flow method of pasteurization, the fruit juice is heated to a temperature about 2.5^{0}C higher than the pasteurisation temperature. The hot juice is filled into hot sterilized bottles upto brim and sealed by crown corking. A care is taken that the temperature of the juice does not fall below pasteurisation temperature during filling and sealing.

In flash pasteurization the juice is heated rapidly to a temperature of 5.5^{0}C higher than pasteurisation temperature for one minute and filled into bottles and canes, sealed air-tight under cover of steam and then cooled. The steam will sterilize the seal. The flash pasteurisation has some advantages, that it helps in minimizing loss in flavour, retention of vitamins, it effects economy in time and space, keep the juice uniformly cloudy, heats the juice uniformly, which reduces to a minimum any cooked taste of the juice. Flash pasteurisation is a type of higher temperature and short time (HTST) heating system.

Some liquid foods are pasteurized after packaging. Food packaged in glass containers is generally pasteurized with hot water. The unpackaged foods such as fruit juices and beverages of low viscosity are pasteurized in continuous operation using plate heat exchangers.

13.6.2 Sterilization

Sterilization is a process of heat application above 100°C, which is employed to deprive microorganisms of their ability to multiply. We can obtain this sterilization temperature by using steam under pressure. The boiling point of water can be raised if the water and steam are enclosed in a strong retort (autoclave). In this retort, temperature increases with increase in steam pressure. The temperature at sea level is 100°C without pressure but at 0.7kg/cm2 steam pressure the temperature of 121°C or above may be easily obtained. At these high temperatures the spores of the heat resistant bacteria are quickly killed. The longer is the heat treatment time at lethal temperatures, the larger is the number of killed microorganisms. At higher temperature, the shorter is the time required to kill microorganisms and lower is heat-included damage to food products.

Theoretically, absolute sterility does not exist. In commercial practice not all cans of food are sterile. However, they usually do not spoil because conditions in the container are not favourable for the growth of concerned microorganisms. The pH may be too low or absence of oxygen. Therefore, the term processing is highly suitable than the term 'sterilization' applied to canned foods.

The foods products low in acid and often high in protein and contain spore-forming bacteria are difficult to sterilize. The acidity of fruits and tomatoes greatly lower the death or sterilizing temperature, which usually explains why acid fruits are easily sterilized.

The purpose of sterilization is the destruction of all pathogenic, spoilage causing organisms and non-pathogenic microorganisms. This process will make the treated product safely preserved at room temperature. Thus, the food products with safe preservation at room temperature are generally defined as commercially sterile.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Describe types of heat treatments.

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2. What is the difference between pasteurization and flash pasteurization?

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3. Explain sterility and commercial sterilization.

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13.7 COMBINATION OF TIME, TEMPERATURE, pH/ ACIDITY

13.7.1 Time and Temperature

The food is generally decomposed by the presence of microorganisms and can be prevented by killing them. The heat preservation is one of the most important methods of killing / inactivation of microorganism as well as enzymes which are already present in the food. Heat application kills the microorganisms because of denaturation of proteins. Different microorganisms have different heat resistance. This can be shown by their thermal death time (TDT) at a particular temperature. For example the TDT of *Lactobacillus bulgaricus* is 30 min. at 71°C; *Escherichia coli* is 20-30 min. at 57.3°C and *Streptococcus thermophylus* is 15 min. at 70-75°C. Thus it is the combination of time and temperature required to kill the specified microorganisms. In a set of given conditions, with increase of temperature the time required to kill cells or spores decreases.

The canning is one of the major methods of food preservation based on destruction of microorganisms by heat treatment and prevention of recontamination. The heat treatment in respect of time and temperature is governed by the nature of food product and size of the container. Thus we can enlist below certain factors, which affect the heat resistance of cells or spores.

i) Initial concentration of spores
ii) The time-temperature relationship
iii) The type and nature of microorganisms
iv) Composition of substrates such as moisture content, pH or acidity, fat, protein, pectin, etc.

The heat treatment based on temperature can be grouped as

i) Pasteurization (heating below 100°C)
ii) Blanching (heating at about 100°C)
iii) Sterilization (heating above 100°C)

You can find more details in Para 13.5 and 13.6.

We can see a time and temperature combination during canning process. The canned food is most sterile when packed; hence the filled cans are exposed to temperature-time profile sufficient to give a safe product. In this process the heat is applied externally which will be the cause of product to lag the surface and bulk product temperatures. Therefore it is essential to estimate the temperature at the slowest heating point. It will also ensure that a product is not over processed. For example canned low acid foods having the pH greater than 4.5 is generally processed at a reference temperature of 121.1°C for 3 minutes at its slowest heating point. Thus, we can consider this thermal process of canned food as safe. If the temperature of thermal process varies, then time will also vary and it can be seen, from the literature. The time – temperature profile as follows: 1.2 min at 125°C; 3.9 min at 120°C; 12.2 min at 115°C; 38.7 min at 110°C; 122.2 min at 105°C and 386.5 min at 100°C.

13.7.2 pH or Acidity

The processing temperature is generally governed by the pH or acidity of food product. The food having a lower pH than 4.6 or higher acidity is generally given low temperature heat treatment. While, food having a higher pH than 4.6 or lower acidity is given high temperature heat treatment.

Food product can be classified based on pH or acidity as follows:

1. *Low acid, pH 5.0 and higher:* This class includes mostly non-acid vegetables and some fruits such as peas, beans, corn, asparagus and bael

fruit, papaya etc. All types of microorganisms including Clostridium botulinum can spoil these products.

2. *Medium acid, pH 5.0-4.5:* Vegetable mixtures, soups, which has partially acidic ingredients. All types of microorganisms also spoil these. The flat sour producing microbes is of importance.

3. *Acid, pH 4.5-3.7:* This group includes tomatoes, pears, pineapple, figs etc. These products can be spoiled by non-spoiling aciduric types, butyric anaerobic and thermophilic anaerobic.

4. *High acid, pH 3.7 and below:* This class includes citrus juices, grape fruits, rhubarb, berries, pickles and sauerkraut.

The bacterial spores are easily destroyed in fruits at pH 3.0 than in vegetables at pH 5.0 and above. These microbial spores do not grow at pH below 4.5. Hence, pH 4.5 has been considered as dividing line between acid and non-acid foods. It is usually practice in canning process. A canned food product, having a pH below 4.5, can be processed at boiling water (100°C). But the food having pH above 4.5 is processed under pressure 0.7 to 1.0 kg/cm^2 to raise the temperature more than 100°C.

The heat inactivation of enzymes in food products is generally governed by time of heat application as well as by pH. Lowering of pH by addition of acids, control enzymatic browning. Acids, which are naturally found in plant tissues such as citric, malic, and ascorbic acids help in reducing enzymatic browning.

13.8 ROLE OF HEAT APPLICATION DURING PRODUCT PREPARATION

Preparation of jam, jelly, juices, sauces, candies etc require a substantial amount of heating. This heat treatment is essential for safe preservation of these products, is being discussed below.

13.8.1 Use of Heat in Jam and Jelly Production

Let us **define** the jam and jelly, marmalade and preserves, and then we will discuss how heat is essential during their preparation.

Jam: Jam is prepared by boiling whole fruit pulp with cane sugar (sucrose) to a moderately thick consistency without retaining the shape of the fruit. As per FPO specification 45 parts of fruit to each 55 parts of sugar, is used for preparation of jam.

Jelly: Jelly is prepared by boiling fruit with water, expressing as water (pectin) extract), adding sugar, and concentrating to such consistency that gelatinization takes place on cooling. The best jelly is clear, sparkling, transparent and of attractive colour. It should retain the shape when removed from container or glass bottle.

Marmalade: Marmalade is a clear jelly in which shreds of peel are suspended. It is generally prepared from citrus fruits.

Preserves: cooking prepared fruit in sugar syrup until the concentration of sugar reaches 55 to 70 percent makes Fruit preserves. In this product, fruits retain its shape and are crisp rather than soft. Here also 45 parts of fruit for each 55 parts of sugar is employed.

Heat in Jam and Jelly Production

Jams

Jams may be made from all varieties of fruits. Good, fully matured fruits are selected, washed, peeled. Thin skinned fruits do not require peeling such as Apricots, plums etc but stone can be removed by machine. Fruits should be boiled in a small quantity of water and steamed and passed through pulper and finisher to get the desired texture pulp. Hence, heating is required to boiling or cooking the fruit to make into pulp. Cane sugar or sucrose is added to the pulp in equal ratio for most of the fruits. But for sweet fruits of low acidity such as ripe peaches, sweet prunes and grapes less than equal weight and sugar is required.

Boiling is an important heat treatment in the preparation of jam, jelly, marmalade and fruit preserves. Boiling or cooking is desirable, it causes intimate mixing of the fruit pulp and sugar. It partially concentrates the product by evaporation of excess moisture. Boiling is again dependent upon the firmness of fruits. Soft fruits in small lots can be concentrated to desired consistency as rapidly as possible. Other hard fruits are more resistant to heat application, may be boiled more slowly. Steam-jacketed stainless steal kettles are commonly used in commercial practice. Vacuum pan is also used to minimize heat damage to the product. Most jam should be concentrated to boiling temperature of 103 to 105^{0}C. The end points of jams boiling vary with fruit varieties, amount of sugar and some other factors. However, the finished jam should show 65 to 68 percent soluble solids as determined by refractometer.

Jelly

The pectin, acid and sugar are essential to the preparation of a normal fruit jelly, out of which pectin is the most important. To make a jelly of excellent consistency, pectin, acid, sugar and water must be in the proper portion. If the fruit is deficient in any one of the constituents, which can be added from outside source. However, we should take proper care in selection of fruits. Fruits rich in pectin, acid and sugars and fully ripe are selected to impart good flavour and texture to the finish product.

The pectin is precipitated as a hydrated colloid that forms a network of fibrils throughout the mass, binding the sugar into the gel. The concentration of sugar makes the texture stiffer. Acid causes the jelly to be the firmer by toughening the fibrils. This is the reason that these constituents must be in the right proportion viz. pectin 1%, sugar 60 to 65%, fruit acid 1% and water 33 to 38%.

Washed fruits are cut into slices or crushed. Very juicy fruits like berries, do not require water, simply they crushed and heated to the boiling point for 2 to 3 minutes and juice or pectin extracted pressed out. Firmer the fruits like apple, guava, oranges are cut or crushed and water is added half to equal volume of the fruits. They are required to be heated to 20 min. Citrus fruits require two to three volume of water for each volume of fruits and require to be heated for 30 to 60 min.

After addition of water, the fruit is boiled and then slowly put on simmering fire for the sufficient time (as mentioned above) to extract pectin, acid and sugars. A clear fruit extract is filtered and tested for pectin content by alcoholic test. The equal amount of juice and alcohol is taken in a centrifuge tube, mixed well, centrifuging, and reading the volume of the sediment. The viscosity of the juice varies with the pectin content hence, the viscosity test by any standard method may be used as a guide for pectin content.

Then fruit extract, sugar, acid are taken in an appropriate proportion. The whole mass is boiled to the end point.

Boiling is one of the important steps in jelly preparation. The boiling dissolve sugar, causes mixing of sugar, acid and pectin to form jelly. During heat treatment certain organic compounds coagulates, which can be skimmed from the surface and their removal make jelly clearer. The principal purpose of boiling is to increase the concentration of sugar to the point where jellying will occur. End point can be measured accurately by use of a thermometer. The thermometer is inserted in the boiling juice. If the juice contains the proper portion of sugar, acid and pectin, the boiling point of the liquid will be a few degrees higher above the boiling point. At sea level the boiling point will be 104 to 105^{0}C and corresponding to a concentration of 65 to 68 percent total solids in the jelly after cooling. This can be also measured by refractometer.

Marmalade

Marmalade preparation is similar to jelly with the difference that it contains pieces of fruit peel suspended there in. The principles of jelly making, apply also to the preparation of marmalade.

Preserves

Fruit preserves should retain the form of original fruit, either whole or cut fruit in clear sugar syrup of higher concentration. Fruit should not be overcooked or caramelized.

Preserves are processed by three different methods viz. open-kettle one-period process, the slow open-kettle process and by vacuum cooking of preserves. Heat treatment is the essential part of these cooking and it influences the quality of the finished products. These three methods are briefly discussed below:

Open kettle one period process: This is a simple method of preserve making and usually employed by housewives. In this process fruit is boiled in steam-jacketed kettles with sugar or in syrup until fruit is impregnated with thick or heavy density syrup. Soft fruits and berries should be boiled for short time. But the firm fruits like peach, pears, aonla require a long period to impregnated them with the syrup. Here, the end point can easily be determined by refractometer at 68 percent soluble solids or by a thermometer, which shows the boiling point about 104 to 105°C at sea level. It is a rapid method with low cost operation, but may result in serious injury to flavour and colour of the finished product.

The slow open-kettle process: In this process the fruit is heated for short time on successive days in sugar syrup of progressively increasing sugar concentration. This will avoid undue injury, to the colour and flavour of the preserves. Initially fruit is boiled enough in syrup containing about 40 percent sugar. Then the mixture kept aside for 24 hours and then further boiled for 3-4 minutes with the addition of 10 percent more sugar. This step is repeated until the product has the desired consistency and then placed in the final containers and sterilized.

Vacuum cooking of preserves: The vacuum cooked preserves are of superior quality in respect of flavour and colour then the preserves made in an open cooker.

The fruit preserves filled into glass jars or can at 88 to 96^{0}C and in commercial practice are generally pasteurized.

Candies: Candied fruits or candies are prepared essentially of slowly impregnating the fruit with sugar syrup until the sugar concentration in fruit is so high enough to prevent spoiling. Repeated boiling and storage in syrups of progressively increasing concentration of sugar generally accomplish this. The fruit is washed and dried to remove excessive sugar from surface. Then it is coated with glaze of sugar and glucose syrup, called glazed or candies. We have learned that heat treatment is essential part of the preparation these products.

13.8.2 Use of Heat in Ketchup and Sauce Production

Tomato ketchup:– Tomato ketchup (catsup, catchup) can be defined that it is a clean, sound product made from strained tomato juice, with spices, sugar, salt, vinegar, onion and garlic etc. It should contain not less than 12 percent tomato solids and 28 percent total solids.

Sauce: It can be defined that the sauce is a clean, sound product made from properly prepared fruits/ tomatoes / peppers with spices, salt, sugar, ginger, onion, garlic etc. It should contain total solids from 12 to 25 per cent.

For preparation of tomato ketchup the first step to prepare tomato juice or pulp for which fully ripe, red coloured fruits are taken. Heat application plays an important role in juice extraction from tomatoes particularly in hot break method. Tomatoes are cut or sliced and immediately heated to boil in their own juice for 3 to 5 minutes to facilitate juicing or pulping. The heat treatments help in the following ways:

1. The pectin present in the skin and seeds can be incorporated into the juice otherwise juice may separate into liquid and pulp.

2. Heat treatment inactivates/destroy the pectate enzymes otherwise hydrolyse the natural pectin present in tomatoes and resulting the thin juice.

3. Boiling tomatoes release the pectin and it thickens the pulp.

4. Boiling sterilizes the tomato juice partly, thereby controlling to some extent the growth of microorganisms, which may cause fermentation etc in the juice.

5. It also inactivates some oxidative enzymes, resulting better retention of vitamin C.

6. The cooking also releases the red colour present in the tomato skin.

7. Heat treatment yield higher juice recovery than cold method.

The tomato ketchup can be made from tomato juice or its concentrate or paste. Here we can say that for preparation of juice concentrate, paste or ketchup the original tomato juice has to be concentrated by application of heat. Thus, heat treatment evaporates water resulting in concentration of juice. The concentration of tomato juice is carried in two ways i.e. by open cooking and cooking under vacuum.

In the **open cooking** – the tomato juice is cooked or boiled in aluminium vessel (Patila), at smaller scale. In large scale, the juice is heated mostly in stainless steel steam jacket – kettle to the desired consistency, which can be measured either by refractometer or specific gravity hydrometer. The open cooking is generally employed, but it has some disadvantages. During cooking the product is exposed to the oxygen in the air, which may destroy vitamin C and makes the juice brown. Sometimes edible oil is added to prevent foaming, boiling, over sticking or burning. It also helps in lessening oxidation.

In **vacuum cooking** – All the above defects are removed in vacuum cooking. In this method the juice is placed in vacuum pan and heated. Under vacuum, boiling takes at reduced temperature of 71°C. This method results in the superior quality of finished product with better retention of vitamin C and colour than open cooking. In the end vacuum is broken and the juice is sterilized by heating to 100°C for about 10 minutes.

Sauce can be made from Soyabean, mushroom, apple and mixtures of various other fruits. Thin sauce is mainly consists of vinegar extract of various flavouring materials like spices and herbs for example Soya sauce, Worcestershire sauce. Thick sauce is highly viscous and contains fruit pulp and more sugar. Their cooking is similar to tomato ketchup.

Similarly fruit juices such as apple juice, pineapple juice, orange juice etc. are also concentrated which can be seen in other blocks and all needed heat treatment.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How heat application works during peeling.

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2 Describe the use of heat application during fruit juice processing.

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3. Explain that the heat processing is greatly influenced by the pH or acidity of the product.

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4. Describe the important role played by heat application in the preservation of jam and jellies.

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13.9 LET US SUM UP

Fruits and vegetables are generally preserved by heat application. Heat treatments are in terms of blanching, pasteurization and sterilization, which also affect the fruit and vegetable compositions, microorganisms and enzyme activity. Heat treatment protects the processed food products from spoilage causing bacteria, moulds and yeasts as well as enzymatic changes.

Heat treatment also made processed food palatable but reduces some of the nutrients. If appropriate time – temperature used and storage at low temperature helps in reducing the nutrient losses. It also enhances their storage life.

Appropriateness of the factors such as salt, sugar, fat, and protein, besides time – temperature and storage temperature also influences the quality and nutrients retention in the processed products.

Heat treatment in various forms is employed during canning process, for peeling, blanching, syrup or brine preparation, filling, exhausting, sterilization etc.

Heat is also applied during product preparation so that jam, jelly, and marmalade etc are set properly. Heat application is also employed in processing of juice and beverage.

Thus appropriate time – temperature depending upon the product and presence of microorganisms and enzymes can manufacture processed products of good quality with proper retention of nutrients.

13.10 KEY WORDS

Pasteurization : process of heating food product to a specific temperature for a specific time to kill the most heat resistant vegetative pathogen.

Sterilization : A process to heat food product to a specific temperature for a specific time to kill the most heat resistant spore-forming organism.

D-value : It is also called "decimal reduction time" or "thermal death rate" and defined as time (in minutes) at a particular temperature (°C) required to kill 90 percent of a microbial population.

Canning : It is defined as preservation of foods in sealed containers and usually implies heat treatment as the principal factor in the prevention of spoilage.

HTST : High temperature short time.

13.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Constituents include carbohydrate, proteins, fats, vitamins, minerals, fibre, water, flavouring compounds

2. Your answer should include the following points:

   - Palatability
   - Storage life
   - Food borne diseases

3. Your answer should include the following points:

   - Blanching - Leaching, thermal oxidation, product damage
   - Pasteurization - Enzymes
   - Commercial - Heating food enzymes
   - Sterilization

4. Your answer should include the following points:

   - Different heat treatment terms are:

UHT, Pasteurization, sterilization, commercial sterilization.

5. Your answer should include the following points:

   - Temperature – time relationship
   - Environment (Nutrients, incubation temperature, state of growth and age, desiccation
   - Substrate composition (moisture, pH, other constituents)

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Blanching
   - Pasteurization
   - Commercial sterilization

2. Your answer should include the following points:

   - Degree of heat application / HTST
   - Time of heat treatment
   - Better nutrition, flavour
   - Minimum cooked taste if any

3. Your answer should include the following points:

   - Heating at higher temperature
   - Complete elimination of microorganisms
   - Destruction of pathogenic, spoilage causing organism

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Types of peeling
   - Heating medium – boiling water, steam, roasting, steam under pressure
   - Softening, cracking, loosening of skin

2. Your answer should include the following points:

   - Heat application – in clarification and preservation of juice
   - Destruction of yeasts and moulds but not killing the spore forming bacteria
   - Time and temperature

3. Your answer should include the following points:

   - Food classification based on pH and acidity

4. Your answer should include the following points:

   - Mixing of fruit and sugar
   - Preparation of pectin or water extract for jelly making
   - Cooking point
   - Temperature of fruit and sugar mixtures

13.12 SOME USEFUL BOOKS

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UNIT 14 DRYING AND DEHYDRATION OF FRUITS AND VEGETABLES

Structure

14.0 OBJECTIVES

After reading this unit, you should be able to:

- know the importance of drying/ dehydration of fruits and vegetables;
- know the drying and rehydration ratio and factors affecting the drying rate of fruits and vegetables; and
- describe the theories and methods of drying and dehydration of fruits and vegetables.

14.1 INTRODUCTION

Drying or dehydration is accomplished by the removal of water from the fruits and vegetables below a certain level at which enzyme activity and growth of microorganisms is affected adversely. The dried or concentrated fruits and vegetable products are called as high sugar high acid foods or high value low volume foods. These dried or concentrated products save energy, money and space in shipping, packaging storing and transportation. Dehydration or drying process usually involves heating, in which water is removed from solid or near solid substances. Both term drying and dehydration mean the removal of water. The term **drying** is generally used for drying of the produce under the influence of non-conventional energy sources like sun and wind. **Dehydration** on the other hand refers to the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and air flow. The sun drying is dependent upon the elements which are beyond the strict control. It is a slow process and thus, not suitable for many high quality products. Generally, it will not lower the moisture contents below about 15% which is too high for storage stability of numerous products. Removal of water from foods provides microbiological stability and assists in reducing transportation and storage costs. Fruit juice is concentrated by evaporating of water and most of the aromatic juice should be heated for short time as possible and cooled rapidly. This minimizes the effect on flavour, aroma, and sugar compounds.

14.2 THEORIES OF DRYING AND DEHYDRATION

There are two steps involved in drying & dehydration.

1. **Heat transfer theory**

   Transfer of heat therefore, consists of transferring some of this molecular or atomic motion from one region to another. There are three broad mechanisms by which such transfer can occur, conduction, convection, and radiation. In conduction, the energy is transmitted from particle to particle by a process of direct contact or random Collin with no bulk movement of material. Transfer of heat by convection involves bulk mixing of fluids of different temperatures. Radiation is the transfer of energy from a radiating source through space which may or may not be occupied by matter. It is by radiation that we receive all our energy from the sun.

2. **Mass transfer theories**

   The removal of moisture from a food product involves simultaneous heat and mass transfer. Heat transfer occurs within the product structure and is related to the temperature gradient between the product surface and the water surface at some location within the product. As sufficient thermal energy is added to the water to cause evaporation, the vapours are transported from the water surface within the product to the product surface. The gradient causing moisture – vapour diffusion is vapour pressure at the liquid water surface, as compared with the vapor presser of air at the product surface. The heat and the mass transfer within the product structure occurs at the molecular level, with heat transfer being limited by thermal conductivity of the product structure, while mass transfer is proportional to the molecular diffusion of water vapour in air. The rate of moisture diffusion can be estimated by the expression for molecular diffusion. The mass flux for moisture movement is a function of the vapour pressure gradient as well as the mass diffusion for water vapour in air, the distance for water vapour movement within the product structure and temperature. The transport of vapour from the product surface to the air and the transfer of heat from the air to the product surface is a function of the existing vapour pressure and temperature gradients, respectively, and the magnitude of the convective coefficient at the product surface.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you mean by drying and dehydration?

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2. What are the main objectives of drying?

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3. What are the main mechanisms by which heat can transfer?

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4. What are the functions of vapour pressure and temperature gradient?

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5. How evaporation is occurred during drying.

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14.3 ADVANTAGES OF DEHYDRATED FRUITS AND VEGETABLES

Fruits and vegetables that are properly dehydrated, particularly to a low moisture level (below 5%) have the following advantages:

1. Dehydration hardly affects the main calorie – providing constituents of fruit. It leaves the mineral content virtually unchanged. Therefore, the process is helpful in preserving the nutritive content of the final product. Vitamin losses are no grater with dehydration than with other preservation methods.

2. Dried fruits and vegetables have an almost unchanged shelf-life under proper storage conditions and there is no grater degree of bacteria, enzymatic changes, and mould actions.

3. Transportation, handling and storage costs are substantially lowered, and need of costly refrigeration during transportation and storage is eliminated Due to their reduction in average weight of $1/7^{th}$ to $1/9^{th}$ of the raw material shipping and handling weight is therefore reduced by approximately 90%.

4. They provide consistent product, an important modern marketing requirement. Seasonal variation in product quality is either absent or at a minimum with low –moisture fruits and vegetables.

5. They provide opportunities for maximum convenience, flexibility, and economics in production because they can be sized, shaped, formed, etc, to fit almost any requirement. With low moisture disposal and pollution problems.

6. They utilize the most economical and disposable from of packaging. The two major considerations in packaging dried fruits and vegetables are the exclusion of moisture and oxygen. Metal cans, plastic bags, and laminated bags and boxes effectively limit the passage of moisture and oxygen.

7. They offer many distinctive conventional as snack products.

14.4 MERITS OF DEHYDRATION OVER SUN DRYING

Dehydration is rapidly increasing importance over the sun drying because of its following characteristics:

1. **Drying conditions**

   Dehydration implies control over climatic conditions within a chamber, or micro environment control. Sun drying is at the mercy of the elements. Dehydration can be carried out throughout the year, irrespective of the prevailing climatic conditions of that region and require less land for drying activities. Sun drying of fruits and vegetables however, can be carried out in limited regions and time during which there is plenty of sun shine and practically little or no rain during the drying season, and require more land for drying activities.

2. **Sanitary conditions**

   In dehydration plant the sanitary conditions are controlled, and dehydration of fruits & vegetables is done under very hygienic conditions whereas in open field's contamination from dust, insect, birds and rodents are major problems.

3. **Relative cost**

   Dehydration has usually somewhat more costly than sun drying but undoubtedly the superior cooking quality of the dehydrated products will cause them to command a sufficiently higher price. For the small orchardist the cost of sun-drying trays is usually less than that of dehydrator, but for the large operator the cost of the dehydrator in some cases be no more than that of sun drying trays.

4. **Colour**

   During sun-drying green or slightly immature cut fruits such as peaches, and apricots, acquires the colour of its fully mature fruits. In dehydration the fruit retains the colour possessed at the time of cutting. Fruit of green, colour retaining this colour after dehydration, therefore, it is essential that fruit used for dehydration be fully mature. If the cut fruit is exposed to the sun for a few hrs before dehydration, the green colour disappear.

5. **Cooking quality**

   Dehydrated fruits, when cooked, more nearly resemble the cooked fresh fruits in flavour and colour than do cooked sun dried fruits. Comparison should be made of the refreshed and cooked fruits rather than the dried fruits. In coking quality, dehydrated foods are usually superior to sun dried counterparts.

6. **Relative yields**

   Dehydration usually gives a somewhat higher yield of dried product (calculated to a common moisture content) than is obtained by sun drying, even under ideal sun drying conditions. This difference is due probably to loss of sugar in sun drying through respiration or fermentation. During cloudy or raining weather loss of sugar in sun drying through fermentation becomes excessive.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why dehydrated products are considered as low cost technology product.

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2. How dehydration is better than sun drying.

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3. How the dehydrated product provide good opportunity for modern market.

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14.5 FACTORS AFFECTING DRYING

Food dehydration involves two steps (i) to get heat into the product and (ii) to get moisture out of the product. The above two steps are not always favoured by same operating conditions. For example food may be pressed between two heated plates. This would give close contact and improve heat transfer into the food through top and bottom, but the close contact of the plates would interfere with the escape of free moisture. Thus it might be better to use one bottom hot plate to get heat in and a free surface on top of the food to let moisture out. The following factors discussed below are playing very important role in affecting the drying rate.

Temperature

The rate of heat transfer into the food which provides the driving force for moisture removal. is affected by the temperature difference between the heating medium and the food. Greater the difference, greater will be the heat transfer and moisture removal. When the heating medium is air, temperature plays a second important role also of carrying away the water driven from the food in the form of water vapour. But the moisture will create a saturated atmosphere at the food's surface which will slow down the rate of subsequent water removal.

Surface area

The heat and mass transfer is affected by surface area and higher surface area result into increased rate of drying. Therefore, the food to be dehydrated is sub divided into small pieces or thin layers which speeds drying for two reasons. First larger surface area provides more surface in contact with the heating medium and thus, more surface area from which moisture can escape. Second smaller particles or thinner layers reduce the distance through which heat must travel to the centre of the food and reduce the distance through which moisture in the centre of the food must travel to reach the surface and escape.

Air velocity

High velocity air, in addition to taking up moisture will sweep it away from the drying foods surface, preventing the moisture from making a saturated atmosphere which would slow down subsequent moisture removal.

Dryness of the air

When the food dried in air, then food will dried rapidly due to more absorption and more holding capacity of moisture by dry air than the moist air . Moist air is closer to saturation and so can absorb and hold less additional moisture,

The extent of dryness of the air also determines how a low moisture content food product can be dried to low moisture content. Dehydrated food is hygroscopic and each food has own its equilibrium relative humidity. Equilibrium relative humidity (ERH) is the humidity at a given temperature where the food will neither lose moisture to the atmosphere nor pick up moisture from the atmosphere.

14.6 PRE-TREATMENTS FOR DRYING OF FRUITS AND VEGETABLES

To obtain excellent quality of a dried product the raw produce needs to be harvested and handled properly. For better quality of dried products following pre-treatments required to be undergo.

Harvesting

To obtain high quality dried fruits and vegetables, the raw product must be harvested at optimum maturity and processed as carefully and rapidly as possible, for example pear is a fruit that is held after picking, because the best quality product is obtained when they are picked green and allowed to ripen in storage.

Washing

Fruits and vegetables are usually rinsed in cold water. To remove surface dust particle and pesticides spray residues, a residual chlorine content of 10-20 ppm of water is recommended to decrease the initial count of raw material to minimum.

Peeling and slicing

Root vegetables, apple and some times cling-stone peaches are peeled prior to drying. This is accomplished by various means: refractory, lye, hot brine peeles, high pressure steam for root crops, mechanical knife peelers for apples and dilute lye for cling-stone peaches. Prunes, grapes, berries and cherries are dried as whole, although latter may be pitted. Apricots, nectarines and peaches are halved and pitted, pears are halved and apples are peeled, cored and either sliced or sectioned.

Pricking

Many pre-treatments given to food before drying are aimed at making the structure more porous to facilitate mass transfer and speedup drying rate. Many pre-treatments are given before drying. Peas, carrots and aonla are pricked to increase the drying rate. Pricking can be done by a hand operated pricking machine. In preserve making the whole fruits, vegetables or their slices are uniformly pricked with stainless steel prickers or forks. Pricking is also useful while preserving fruits and vegetables by osmotic dehydration.

Soaking

The fruits and vegetables slices after pricking are soaked in plan water, lime water, brine or alum solution for few hrs to few days before blanching and cooking.

Curing

Curing is practiced in onion and garlic. It dehydrates raw material by sun drying or by hot air drying at a temperature of 30°C. In garlic it is carried out until the segments can be easily separated.

Alkaline dip

Alkaline dip is used primarily for fruits that are dried as whole especially prunes and grapes. Dipping facilitates drying by forming fine cracks in the skin. A sodium carbonate or lye solution (0.5% or less) is used at a temperature ranging from 93-100°C.

In Australia and some Mediterranean countries cold dip solution such as carbonate or lye with olive or commercial solution are used. The main active ingredients of commercial solution are oleate esters. These dips accelerates moisture loss by causing the wax plates on the grape skin to dissociate thus, facilitating water diffusion.

Acid dip

Before sulphuring use of an acid pre-dip provides better colour stability to a product. A dip of 1% ascorbic acid and 0.25% malic acid has been used to retard enzymatic browning in peaches. Steeping of mushrooms in 0.5% to 1.0% citric acid for 16 hrs results into better quality dried products in respect of colour, appearance, rehydration properties and keeping quality. .

Blanching

Blanching is a partial pre-cooking treatment in which vegetables/ fruits are usually heated in water or in live steam to inactivate the enzymes before processing.

Purpose of blanching

- Reduces drying time
- Removes inter- cellular air from the tissues
- Causes softening of texture
- Retards the development of objectionable odour and flavour during storage by enzyme inactivation
- Retain carotene and ascorbic acid during storage
- Removes pungency (onion)
- Impart desired translucent appearance to the product.

Sulphuring

The whole fruits, slices or pieces are exposed to the fumes of burning sulphur inside a closed chamber known as sulphur box for 30-60 minutes.

Purpose of sulphuring

- Prevent oxidation and darkening
- Act as preservative/ antimicrobial agents
- Check the growth of moulds
- Prevent cut fruits from fermentation
- Prevent the vitamin losses

Sulphiting

Sulphitation is a process in which the product is dipped in a SO_2 in water.

Purpose of sulphiting

- Maintains an attractive colour
- Prevents spoilage
- Preserves certain nutritive attributes until marketing
- Act as antioxidants and protect the carotene and ascorbic acid content of dried fruits.

Post drying treatments

The practices as post drying treatments which are followed after drying are described as follow:

Sweating

Sweating is a practice of storage of dried product in bins or boxes for equalization of moisture or re-addition of moisture to a desired level. It is used primarily with some dried fruits and some nuts (almonds and walnuts).

Packaging

Most product are packaged after drying for protection against moisture, contamination with micro-organisms, and infestation with insect , although some dried foods (e.g. fruits and nuts) may be held as long as a year before packaging.

In-package desiccant

In package desiccant means the packaging of the dried product with a material like calcium oxide or silica' gel that will continue to absorb the remaining moisture during storage. Silica gel @ 1 to 2% in powdered foods, prevent moisture picking after seal of the package and brought down the moisture from 3% to 1% n case of orange juice powder without a significant loss of vitamins at 21.1 to 67.8°C for 6 months and thereby, eliminating caking.

Pasteurization

It is usually limited to dry fruits to kills any pathogens that might be present as well as destroys spoilage organisms. The fruits usually pasteurized in the package and the treatment varying with the fruits is from 30-70 min at 100% relative humidity at 65.6 to 85°C.

FRUITS/VEGETABLES
(mature and free from insects and diseases)
↓
WASHING
↓
PEELING
↓
PREPARATION
(as given in table for individual fruit/ vegetables)
↓
BLANCHING
↓
SPREADING ON FALAT WOODEN TRAYS
↓
SULPHURING
(usually @ 1.8 to 3.6 kg/ ton of fruit)
↓
DRYING /DEHYDRATION
(with occasional turning)
↓
SWEATING
↓
PACKING
(air tight tin containers or polyethylene bags)
↓
STORAGE
(at ambient temperature in dry place)

Figure 14.1: Flow-sheet for drying/dehydration of fruits and vegetables

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the factors which affect the drying rate?

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2. Explain why it is necessary to use bottom as hot and free surface on top during drying.

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3. Describe the role of temperature in drying.

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4. How the surface area affect the drying rate.

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5. How product size affect the drying rate.

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6. What is the role of pricking in fruits and vegetables?

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7. Why hole fruits are generally treated with alkaline solution?

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8. What are the main purposes of blanching?

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14.7 DRYING RATE

The initial removal of moisture occurs as the product and the water within the product start evaporation due to slight increases in temperature and followed the initial stages of drying . A significant reduction in moisture content then will occur at a constant rate and at a constant product temperature. The constant-rate drying period occurs within the product at the wet bulb temperature of the air. While the most situations, the constant rate drying period will continue until the moisture content is reduced to the critical moisture content. At moisture content below the critical moisture content, the rate of moisture removal decreases and followed the falling rate drying period.

14.8 DRYING AND RECONSTITUTION RATIO

Drying ratio

Drying ratio is always vary with the type of variety, growing conditions, time of harvest, grade of raw material and loss in preparation. In this connection, dehydration ratio should not express on the basis of moisture percent in the material, but it should be expressed on a dry basis i.e. as the ratio of water content to dry matter. The weight of dry matter going into the dryer will be the same as that taken out. The amount of water changes, but the dry matter does not.

Knowing the water content of the fresh material entering the dryer and of the product leaving the dryer, the drying ratio, or its reciprocal drying yield, can be calculated as follows.

$$\text{Drying ratio} = \frac{\text{Weight entering dryer}}{\text{Weight leaving dryer}} = \frac{100 - \text{M1}}{100 - \text{M0}} = \frac{\text{TO} + 1}{\text{T1} + 1}$$

Where M0 = is the percent moisture of the material entering the dryer,
M1 = percent moisture of the product leaving the dryer
T0 = lb of water per lb of bone-dry material entering the dryer
T1 = lb of water per lb bone-dry material leaving the dryer.

For example, potatoes, prepared and ready for the dryer, have about 78 percent moisture, when properly dried they have about 7 percent moisture. Then

M0 = 78, M1 = 7, T0= 78/22 = 3.55, T1 = 7/93 =0.075

$$\text{Drying ratio} = \frac{100 - 7}{100 - 78} = \frac{3.55 + 1}{0.075 + 1} = 4.23 = 4.23:1$$

$$\text{Drying yield} = \frac{100 - 78}{100 - 7} = \frac{0.075 + 1}{3.55 + 1} = 0.236 \text{ or } 23.6 \text{ percent}$$

It should be noted that the over all ratio between weight of raw material entering the plant and weight of finished product leaving it must take into consideration losses incurred during preparation and final inspection.

Reconstitution ratio

Rehydration means the quantity of water absorbed by dehydrated foods.

Calculation can be made to express the results in terms of rehydration ratio" "coefficient of rehydration" and "percent of water in the rehydrated material"

Examples of such calculations are as follows:

Rehydration ratio

Suppose the weight of the dehydrated sample used for the test is 10 g (W_D) and the drained weight of rehydrated sample is 60 g (W_R).

Then $= \frac{W_R}{W_D} = \frac{60}{10} = \frac{6}{1}$, the rehydration ratio is 6 to 1 = 6:1.

Coefficient of rehydration

The drained weight of the rehydrated sample is 60 g (W_R), the weight of the dehydrated sample is 10 g (W_D) and contain 5 per cent moisture (W_M), and the original material before dehydration contained 87 percent moisture (A). Then

$$\frac{W_R}{\frac{(W_D - W_m)100}{100 - A}} = \frac{60 \times (100 - 78)}{10 - (10 \times 0.05)} = \frac{780}{9.5} = 82\% \text{ or } 0.82$$

Percent of water in rehydrated material

Knowing the drained weight of the rehydrated sample, the percent of water in the rehydrated material can be calculated;

$$\frac{60 - 9.5}{60} \times 100 = \frac{5050}{60} = 84.1\%$$

Note: For better rehydration it is suggested that the following conditions be met.

1. Detrmine the time of soaking and boiling that is compatable with optimum quality of the product.
2. Start the test with at least enough water to submerge the pieces , but do not use so much water that excess amount are present at the end of the test.
3. Shake or stir if necessary to insure wetting of all pieces during the test.
4. Control the rate of heating so as to prevent rapid and variable losses of water while boiling.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the constant rate and falling rate period?

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2. Differentiate between drying and reconstitution ratio.

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3. What are the factors which affect the reconstitution ratio?

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14.9 ROLE OF WATER ACTIVITY AND ITS IMPORTANCE IN DRIED PRODUCTS

Water activity (a_w) is defined as the ratio of the vapour on the aqueous solution to that of pure water at the same temperature i.e.

$$a_w = \text{Vapour pressure of solution at T°C}$$

Vapours pressure of pure water at T°C.

Water activity is also equal to the equilibrium relative humidity (ERH);

$$a_w = \frac{\text{Equilibrium relative humidity}}{100}$$

The a_w has a major role to play on microbiological spoilage and chemical changes produced in the food. The principles of water and microorganisms relation includes:

i) water activity, rather than water content determines the lower limit of available water for microbial growth. Most bacteria do not grow below a_w 0.91 and most moulds cease to grow at water activity of 0.80. Some xerphylic fungi have been reported to grow at water activities of o .65, but the range of 0.70 – 75 is generally considered their lower limit.

ii) Environmental factors affect the level of water activity required for microbial growth. The less favourable the other environmental factors (nutritional adequacy, pH, oxygen pressure, temperature) the higher becomes the minimum a_w at which microorganisms can grow.

iii) Some adaptation to low water activities occurs, particularly when a_w is depressed by addition of water soluble substances (principle of IMF), rather than by water crystallization (frozen foods) or water removal (dehydrated foods).

iv) When water activity is depressed by solutes. The solutes themselves may have effects which complicate the effect of a_w per se. For instance, at a given a_W microbial growth is less effectively depressed by glycerol than by sodium chloride. More recent (IMF) have resulted in the following additional findings.

a) Water activity modifies sensitivity of microorganisms to heat, light and chemicals. In general organisms are most sensitive at high water activities (i.e. in dilute solution) and minimum sensitivity occur in an intermediate moisture. Minimum water activities for production of toxins are often higher than those for microbial growth. The phenomenon may represent an important safety factor in the distribution of dehydrated and intermediate moisture foods.

b) The effect of water on chemical reactions in foods are more complicated than are its effect on microbial growth. It plays one or more of the following roles; a) as a solvent for reactant and for products, b) as a reactant (e.g. in hydrolysis reactions) c) as a product of reactions and d) as a modifier of the catalystic or inhibiting activities of other substances (e.g. water in activities some metallic catalysts of lipid per oxidation).

14.10 COMMON TYPES OF DRIERS USED FOR DRYING OF FRUITS AND VEGETABLES

A) Solar driers

These are suitable for drying of onion flakes. The matrix type solar air heater consists of an iron scrap as an absorber. The upper surface of this matrix is painted dull black. Air is made to flow through the matrix in the upwards direction. Similarly in rock type solar air heater is connected with the cubic shaped dehydration chamber, through an air duct of appropriate dimension. Dehydration chamber has provision for holding trays and thermometer a glass door and a chimney. Solar driers are different types like tent type drier, walk-through drier, air flow inside indirect drier cabinet, indirect chimney driers etc.

B) Air convention driers

Air convection driers have some sort of insulated enclosure, a means of circulating air through the enclosure and a means of heating this air. They also have various means of product support and special devices for collecting dried product, some have air driers for lower drying air humidity. Movement of generally is controlled by fans, blower and baffles. The air may be heated by direct or indirect methods. In direct heating the air is in direct contact with a flame or combustion gases. In indirect heating the air is in contact with a hot surface such as pipes or fins heated by steam, flame or electrically.

1. Kiln driers

This is the one of the simplest kind of air convention drier. In this dryer a furnace or burner on the lower floor generated heat and warm air rises through a slotted floor to the upper storey. Food such as apple slices spread out on the slotted floor of drier and turned-over periodically. This type of drier generally will not reduce moisture to below 10%. A rotary kiln drier dries the product in a rotating drum using a burner to blow hot air into the drum along with the product. Because of higher temperatures of drying, this method has some limitations with respect of limited nutrient levels and off- colour of the finished product.

2. *Cabinet tray and pan dryers*

Cabinet drier are suitable for small scale operations. Fresh air is drawn by the fan through the heater coils, filtered by screened to remove dust, and than blown across the materials on trays to an exhaust system. The air may pass across and between the trays or may be directed up through the perforated trays. Cabinet tray and pan driers are comparatively inexpensive and easy to set in forms of drying conditions. These may run up to 25 trays high and will operate with air temperature of about 93°C (200°F) dry bulb and air velocities of about 2.5-5 m/s across the trays. They are commonly used to dry fruit and vegetable pieces and depending upon the food and the desired final moisture, drying time may be of the order of 10-20 hrs.

3. *Tunnel and continuous belt driers*

The main construction feature by which tunnel driers differ is the direction of air flow relative to tray movement. When the direction of air flow and that of tray movement is opposite, then it is counter-flow or counter current principle. Its significant is that the air ,when it is the hottest and dries, contacts the nearly dry product, whereas the initial drying of entering carts get cooler, most air that has cooled and picked up moisture going through the tunnel. Since the initial product temperature and moisture gradients will not be great, the product is less likely to undergo case hardening or other surface shrinkage leaving wet centres. Further, lower final moisture can be reached since the dried product encounters the driest air. In contrast, there are also co-current flow, tunnels with the incoming trays and dry-hot air travelling in the same direction. In this case, rapid initial drying and slow final drying cause case hardening, internal splits and porosity as centres finally dry, which sometimes is desirable in special properties.

The common features of the dryer include uniform automatic feeding of product to the belt in a controlled thin layer, zone heat and air flow control in different sections, tumbling over the product onto a second strand of belt, automatic collection of dried product and of course continuous operation.

4. *Belt trough driers*

A special kind of air convection belt driers is the belt trough drier in which the belt from a trough and belt is usually made up of metal mesh and heated air blown up through the mesh. The belt moves continuously keeping the food pieces in the trough in constant motion to continuously expose new surface. This speeds-up drying with air of about 135°C (272°F) vegetable pieces dried to 7 to 5% moisture range in about 1 hr. High operating temperatures result in high drying rates without causing appreciable heat damage to vegetable pieces because the constant agitation keeps individual piece from being exposed to the very hot dry air for more than a movement. Then, each piece is surrounded by air at much lower temperature for a longer time before again moving into the zone of intense drying,. Onion slices dried in this way tend to separate and become entangled. Fruit pieces that exude sugar on drying tend to stick together and clump with the rumbling motion.

5. *Air lift drier*

Several types of pneumatic conveyer dryers go a step beyond tem being to exposure more surface area of food products. These dryers tem being to finish dry materials that have been partially dried by other methods, usually to about 25% moisture or at least sufficiently low. So that the material becomes granular rather than having a tendency to clump and mat. A product from drum drier having 25% moisture can be brought to about 6% moisture more efficiency in a heated air steam than on the drum. This is because it is more difficult to remove moisture in this falling rate of dehydration. The suspended particles when dry are separated from the air and collected in a cyclone type separator.

6. *Fluidized bed drier*

Another type of pneumatic conveyor drier is the fluidized bed drier. In fluidized bed drying heated air is blown up through the food particles with just enough force to suspend the particles in a gentle boiling motion. Semi dry particles such as potato granules gradually migrate through the apparatus until they are discharged dry. Heated air is introduced through a plate that supports the bed of granules. The moist air is exhausted at the top. This process is continuous and the duration of time that the particles remain in the drier can be regulated by the depth of the bed. This type of drier can be used to dehydrate peas and other particles. Fluidized bed drying has numerous advantages such as a) high drying intensity, b) uniform and closely controllable temperature throughout, c) high thermal efficiencies, d) time duration of the material in the drier may be chosen arbitrarily, e) elapsed drying time is usually less than in other types of drier, f) equipment operation and maintenance are relatively simple, g) the process can be automated without difficulty, h) fluidized drier are compact and relatively small, i) several process may be combined in a fluidized bed drier.

7. *Spray drier*

By far the most important kind of air convection drier is the spray drier which is used widely for dehydrating liquid food products. It is limited to foods that can be atomized (liquid and low viscosity passes or purees). Automization into minute droplets results in drying in a matter of seconds with common inlet air temperatures of about 204^{o}C. The liquid product to be dried is automized into a chamber, where it is put in contact with a stream of hot air and rapidly dried. The dry particles suspended in air stream, flow into separation equipment where they are removed from the air, collected and packaged or subjected to further treatment, such as instantizing. A wide range of products like banana, potatoes, proteins from various plants sources, soy isolates, citrus juices, tomato puree corn hydrolysates etc. have been successfully drying by this dryer.

8. Bin dryer

Bin drier are used, particularly for pieces from of vegetable products to complete the drying operation. Usually it is a finishing step after truck apron or tunnel drying during which most of the moisture has been removed. Typically, a bin drier reduces the moisture content of a particularly dried products (10-15% moisture) cut vegetable to 3-6% or even lower in the case of onion slices and possibly cabbage shreds. Win dryer consists of a metal or wooden box equipped with an air inlet at the bottom and a wire mesh deck or false bottom with an air supply duct below it so arranged that warm dry air can be passed through the nearly dry product piled on the deck.

C) Roller drier

Roller drier consists of one or two hollow drums which are fitted so that a heating medium, usually steam but occasionally water or a special high temperature, heat transfer liquid can be directed through them. The drums are mounted to rotate about the symmetrical axis and are customarily driven with a variable speed mechanism, feeding device applies a thin, uniform, layer of the material to be dried on the hot drum surface. A knife or doctor blade is fitted to the drum at an appropriate location. The material is dried as the heated drum rotates towards the doctor blade which scrapes the thin layer of dry material from the drum surface.

1. Drum drier

In drum drying liquid foods, purees, pastes, and mashes are applied in a thin layer onto the surface of a revolving heated drum. The drum generally is heated from within by steam. Driers may have a single drum or a pair of drums. The food may be applied between the nip where two drums comes together, and then the clearance between the drums determines the thickness of the applied food layer. Drum drying has some inherent limitations which restrict the kinds of foods to which it is applicable. To effect rapid drying drum surface temperature must be high generally above 121°C. This give product, a more cooked flavour and colour than when they are dried at a lower temperature. Another limitation is the difficulty of providing zoned temperature control needed to vary the drying temperature profile. With a modified atmospheric double drum drier and with appropriate separating conditions, fruit and vegetables flakes are produced with commercial success. The vapour which evolved during drying are exhausted through hoods over and under the drums. The product collection zones are maintained at about 10-20% RH. Drum drying process are used successfully in the production of powdered cranberries, tomato cocktail, pea and bean soups, apple, flakes, potato flour, tomato juice flakes, mashed flakes and sweet potato flakes.

2. Foam-mat drier

Foam-mat driers are used primarily for liquids which are pre-foamed by whipping, adding a few level of an edible whipping agent-to liquids that do not whip readily. Foaming a liquid exposes enormous surface areas for quick moisture removal which also permits use of lower drying temperatures. Foam is deposited in a uniform layers of many foods can be dried to about 2-3% moisture in approximately 12 min.

D) Vacuum dryers

In vacuum drying the temperature of the food and the rate of water removal are controlled by regulating the degree of vacuum and the intensity of heat input. Heat transfer to the food takes place largely by conduction and radiation. Vacuum drying methods usually can be controlled with a higher degree of accuracy than the n method which depends upon air convection heating. All vacuum drying system have four especial elements: a vacuum chamber of heavy construction to with stand outside air pressure that may exceed internal pressure by as much as 9800 kg/m^2 a heat supply, a device for producing and maintaining the vacuum, and components to collect water vapour as it is evaporated from the food.

1. *Vacuum puff drier*

   Vacuum puff drier refers to the dehydration of liquid materials in vacuum by evaporating water under pressure in excess of 1 mm of Hg, so that the products puff during drying and form expanded honey combed structures. This process is distinguished from freeze drying in that latter is done under extremely low pressure, always well below 1 mm and sometimes as low as 5 µm, with the materials in a frozen state.

   In puff drying of juice, a porous structure is obtained by applying vacuum to a viscous juice concentrate when bubbles of water vapour and entrapped air formed expand throughout the material. Vacuum temperature and velocity of the concentrate are controlled so that the puffed material has about 20 times the volume of the liquid concentrate. In certain juice such as tomato, which have low soluble solids content and a high insoluble solids or pulp content, puffing is not satisfactory unless air or another gas is incorporated into the concentrate.

2. *Vacuum shelf puff driers*

   One of the simplest kinds of vacuum driers is the batch type vacuum shelf drier. If liquids such as concentrated fruit juices are dried above 5 mm Hg, the juice boils and splatters, but in the range of about 3 mm Hg and below, the concentrated juice puffs as it losses water vapour. The dehydrated juice then retains the puffed spongy structure. High vacuum dehydrator operates at fractions of a millimetre of mercury. At 2 inch or 50 mm of mercury pure water boils at 38°C. Since temperatures well below 38°C (101° F) can be used, in addition to quick solubility there is minimum flavour change or other kinds of the heat damage. It is also suitable for the dehydration of food piece.

3. *Continuous vacuum belt puff drier*

   The drier consists of a horizontal tank like chamber measuring about 17m length and 3.7 m in diameter. The chamber is connected to a vacuum producing moisture condensing system. Two revolving hollow drums are mounted within the chamber and a stainless steel belt is connected around the drums which move in a counter clockwise direction. The drums on right as heated with steam confined within it. The drum heat the belt passing over it by conduction. As the belt moves it is further heated by infrared radiant elements. The drum to the left is cooled with cold water circulated within it and cools the belt passing over it. The liquid food in the form of a concentrate is pumped into a feed pan under the lower belt strand. An applicator roller dipping into the feed continuously applies a thin coating of the food onto the lower surface of the moving belt. The food is dried in a vacuum equivalent to 2 mm Hg. When the food reaches the cooling drum it is dried to about 2% moisture. At the bottom of cooling drum is a doctor blade which scrapes the cooled, product, into collection vessel. It is used commercially to dehydrate high quality citrus juice crystals and other delicate liquid foods. Products dried with this equipment have a slightly puffed structure.

E) Freeze driers

Freeze dryers are used to produce dehydrated foods of exceptional quality. In freeze dryers the material such as fruit juice concentrate, is first frozen on trays in the lower chamber of a freeze driers and the frozen material dried in the upper chamber under high vacuum. The material dries directly by sublimation of ice with out passing through the intermediates liquid stage. The dried product by this method is highly hygrospic. It reconstitutes readily. Mango pulp, orange juice concentrate and guava pulp have been found to give freeze dried powders of excellent quality in regard to taste, flavour, reconstitution properties etc.

F) Slush driers

Slush driers are used to obtained the benefit over the freeze dryer and air or vacuum drying without the drawback of drying from a partially frozen state where in 20-70% of water present is frozen with remainder being liquid. The high dissolved solid contents of the liquid portion of the mixture aids volatiles relation and the need for maintaining the ultra low temperature requirement for freeze drying is avoided.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define water activity (a_w).

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2. What are the common features of tunnel drier?

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3. What are the advantages with fluidized bed driers?

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4. How the mass and heat transfer is controlled in vacuum drier.

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14.11 IDEAL CONDITION FOR PACKAGING AND STORAGE OF DRIED PRODUCTS

Packaging is an integral part of processing. It provides a barrier between the food and the environment. It controls light transmission, transfer of heat, moisture and gas, and movement of microorganisms or insects. The shelf life of a dehydrated product is influenced to a large extent by the packaging. So package must confirm the following special criteria:

a) Protection of the dehydrated product against moisture, light, air, dust, micro flora, foreign odour rodent etc.

b) Strength and stability to maintain original container properties through storage, handling and marketing.

c) Size, shape, appearance to promote stability of the product.

d) Composition of the container must be approved for use in contact with foods.

e) Cost of the package should not be more than the cost of content packed inside of the package.

Dried fruits and vegetable should be quite dry and should be packed in moisture proof container such as tin container. If care is not taken to guard against entry of excessive moisture the contents inside the package become mouldy. Wooden boxes or cardboard containers are not generally moisture proof and insect proof unless special methods are adopted to line them. Proper packaging of dehydrated fruit and vegetable products prevents, deterioration and spoilage during storage under ordinary conditions, as well as under extra ordinary conditions. With the recent introduction of a variety of plastic packaging materials and film, a great deal of research work has been carried out in many parts of the world to develop suitable packaging. In the case of fruit juices powders, some spice products etc their packaging becomes highly critical and decisive. Packages based on cheap indigenous materials such as brown casing paper (60 gauge) aluminium foil (0.0mm) polyethene (150 gauge) pouches with a 2 ply corrugated liner wax ed carton, etc have been developed to ensure a minimum shelf life of one year under field conditions.

Dried and dehydrated foods should be stored in a dark, dry, cool, place, and lower the temperature of storage, longer the life of the product. Storage practices for dried fruits are variable, but a temperature of 40°F is commonly used with little attempt humidity control. The best storage for most dried fruits is 32°F and 55 percent relative humidity. Some fruits such as dried apples, apricots and peaches, do not seem to be harmed by 80 percent relative humidity at 32°F. Other particulars raisins and figs gain moisture, and sugar to a harmful extent at this humidity.

14.12 DRYING PROCESS FOR FRUITS AND VEGETABLES

The process used for drying of individual fruit and vegetable is described as follows:

Fruits

Grapes: Raisins prepared from grapes are the most important dried fruit product. Muscat and wine varieties are dipped in boiling solution of 0.5% caustic soda followed by rinsing and sulphuring for 1 hr and then, drying at 55-60°C in a dehydrator or sun drying. Ripe bunches of grapes are hung inside the dark rooms known as Kishmish khanas till berries acquire a greenish or light amber tint colour. Monucca or raisins is prepared from large seeded Haitha grapes which are lye dipped prior to sun drying. In California, the Sultana or Thompson seedless grapes are dried.

Banana: Washing, peeling, cutting, into halves lengthwise or crosswise (12 mm thickness), sulphuring for 30 min followed by drying at 55-60°C in a mechanical or solar drier.

Prunes: Washing, cleaning, pitting perforation and drying.

Apricot: Washing, cutting, into halves, destoning, sulphuring for 30 min. followed by drying at 50-60°C in a mechanical or solar drier.

Mango: Washing, peeling , cutting into 12 mm thick slices, sulphuring for 2 hrs followed by drying at 45-50°C in a mechanical or solar drier. Ripe mangoes are taken and juicy squeezed by hand and dried as Aam pappad.

Date: Washing, dipping in boiling solution of 0.5% caustic soda followed by rinsing and drying in a dehydrator at 45-50°C.

Fig: Washing, sulphuring for 1 hr followed by drying at 55 to 60°C in a mechanical or solar drier.

Aonla: Washing, grating followed by addition of salt @ 40 g/kg to the grated material and then, drying in mechanical or solar drier.

Apple: Washing, peeling, coring, trimming and slicing into 5 mm thickness, followed by sulphuring for 30 min or immersion in 1-2 % KMS solution for 30 min. This follows the drying at 60-65°C in a mechanical or solar drier.

Papaya: Washing, peeling, removal of seeds, cutting into 6 mm thick slices, sulphuring for 2 hrs followed by drying at 60-65°C in a mechanical or solar drier.

Pear: Washing, peeling, cutting into halves, holding in 1-2% salt solution, sulphuring for 30 min. or immersion for 20 min in 1-2%KMS solution followed by drying at 60-65°C in a mechanical or solar drier.

Peach: Washing, stone, peaches like july Elberta cultivars is used for drying. The drying process includes washing, removal of pits, cutting into halves, sulphuring for 30 min followed by drying at 60-65°C in a mechanical or solar drier.

Other Fruits: Pomegranate seeds are dried into Anardana, cherries and berries are also dried.

Varieties of the common fruits suitable for drying

Apples	Baldwin, Bellflower, Delicious, Gravenstein, Hoover, Jonathan, king, Yellow Newtown, Permain, Rhode Island greening, Rome Beauty, Wagener, Winesap
Apricot	Blenheim, Royal, Tilton
Figs	Adriatic, Black Mission, Calimyrna, Kadota
Nectarins	Hardwick, Newboy, Quetta, Stanwick
Peaches	California midsummer varieties and Phillips cling
Peaches (freestone)	Elberta, Lovell, Muir
Pears	Bartlett
Prunes	French, Imperial, Sugar, Robe de Sergeant
Raisins 9Golden bleached) dehydrated	Thompson Seedless
Currants (Zante)	Black Corinth

Vegetables

Onion and *garlic* make excellent dehydrated product: onion is dried in the form of flakes and powder whereas; garlic is dried as cubes and powder. Their use in the dry form has great scope particularly for export point of view.

Beans: Washing, peeling and cutting into 10 mm thick slices, steam blanching for 10 min. followed by drying at 60-65°C in mechanical or solar drier.

Beet: Washing, peeling and cutting into 10 mm thick slices, steam blanching for 10 min. and drying at 60-65°C in mechanical or solar drier.

Bitter gourd: Washing, removal of both ends cutting into 10 mm thick slices, blanching for 7-8 min. and drying at 65-75°C in mechanical or solar drier.

Brinjal: Washing, cutting lengthwise into 10 mm thick slices, blanching for 4-5 min and then, immersion for 1 hr in 1% KMS solution followed by drying at 50-52°C in mechanical or solar drier.

Cabbage: Washing, removal of outer leaves and cutting into fine shreds, blanching for 5-6 min, immersion for 10 min in 0.5% KMS solution and draining by drying at 55-60°C in mechanical or solar drier.

Cauliflower: Washing, removal of stalks, covering leavers and steams, breaking of curd suitable size pieces, blanching for 4-5 min. immersion for 1 hr in 1% KMS solution and draining followed by drying at 55-60°C in mechanical or solar drier.

Carrot: Washing, scrapping, stalks and tips, cutting into 10 mm thick slices blanching for 2-4 min. in boiling solution of 2% salt followed by drying at 60-65°C in mechanical or solar drier.

Chilies (red): Mature dark red pods are tied to a string and hanged in sun or dried at 50-55°C in a dehydrator.

Green peas: Washing removal of shell, blanching grains in boiling water or steam for 3-4 min. immersed in 0.5% KMS solution and draining followed by drying at 60-65°C in mechanical and solar drier.

Palak, methi and other leafy green vegetables: Sorting, washing, trimming-off rough stems and stalks and shred making followed by blanching for 2 min in boiling water or steam and then drying at 60-65°C in mechanical or solar drier.

Potato: washing, peeling, and cutting into 10 mm thick slices, blanching in boiling water or steam for 3-4 min. and immersion in 0.5% KMS solution followed by drying at 60-65°C in mechanical or solar drier.

Tomato: washing, blanching for 30-60°C, peeling and slicing into 1 cm thick slices followed by drying at 60-65°C in mechanical or solar drier.

Turnip: Washing, removal of stalk, peel, cutting into 5 mm thick slices, blanching for 2-4 min. in boiling water then immersion for 1-2 hr in 1%KMS solution, followed by drying at 50-55°C in mechanical or solar drier.

Mushroom slices: mushrooms are one of the most important vegetable prepared by dehydration. Steps include trimming, blanching with SO_2 @ 500-1000 ppm for 5-10 min. slicing followed by drying in mechanical or solar drier.

Ginger: trimming, washing, cutting or slicing and drying in mechanical or solar drier.

Drying schedule for fruits

Fruits	Preparation	Pretreatments (in boiling lye solution 0.2% NaOH)	Time of sulphuring (min)
Apple	Peel, core and cut in 5 mm thick slices	-	15-30
Apricot	Wash halves destine	-	20-25
Peach	Halves peel, destine	-	20-25
Grape	Wash	2-5 sec.	10-15
Banana	Wash peel, cut into thick slices	-	2 hrs
Mango	-do-	-	2 hrs
Papaya	Wash peel, cut into 5 mm thick slices	-	2 hrs
Pine apple	-do-	-	2 hrs

Drying schedule for vegetables

Vegetables	Preparation	Blanching in boiling water	Sulphitation in 0.5% KMS
Potato	Peel cut into 3mm thick slices	3-4 min	30 min
Carrot	-do-	4-5 min	30 min
Okra	Remove both ends and cut into 6mm thick slices	5-6 min	30 min
Cabbage	Remove outer leaves and cut into 4-8 mm thick shreds	5-6 min	30 min
Cauliflower	Remove stalks leaves and stem cut into 10 mm thick slices	5-6 min	30 min
Peas	Shelled peas	3-4 min in boiling water containing 0.5% KMS,0.1% Sodium bicarbonate and 0.1% magnesium oxide	30 min
Spinach	Short, wash thoroughly in water and cut into 10 mm portion	-do-	Nil

Fenugreek	Short, remove stalks and stem and wash leaves thoroughly	Blanch above for 2-3 min	Nil
Onion	Remove tops and tails, peel and cut into 4-8 mm thick shreds	Nil	Nil
Garlic	Peel and cloves cut into 6 mm thick shreds	Nil	Nil
Bitter Guard	Remove both end and cut into 6mm thick slices	Blanch in boiling water	30 min
Pumpkin	Peel remove seeds, and cut soft portions into 6mm thick slices	2 min	30 min

Check Your Progress Exercise 6

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the functions of packaging?

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2. What is the optimum storage temperature and relative humidity for dried products?

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14.13 LET US SUM UP

Dehydration or drying is an important and oldest preservation method in food processing. Water removal from food is primarily done to lower the water activity (a_w) so that microbial growth is inhibited. It also saves energy, moisture and space in shipping, packaging, storage and transportation of dried fruit and vegetable products. These are known as high value low volume food or high acid high sugar foods. Prolong heat processing of fruits and vegetables affect their delicious flavour, nutritional quality and acceptability. In recent years, the achievements in the drying / dehydration of fruits and vegetables have led to the development of more improved methods and techniques of drying including water removal at low or ambient temperature. These techniques include osmotic dehydration, foam-mat drying (especially micro flake process), modified drum drying, explosion puffing, slush drying, vacuum drying, freeze drying etc. Various treatment have been developed for treating fruits and vegetables to increase the rate of drying or decrease the drying time to reduce the production of brown pigment. So by using these techniques, the overall quality of the dried products including sensory and nutritional value, has been improved.

14.14 KEY WORDS

Water activity	:	Water activity (a_w) is the ratio of vapour pressure of food (P) and pure water (p_o) and expressed by aw = p/p_o.
Dehydration	:	Removal of moisture under control conditions of temperature, air flow and humidity.
Drying	:	Drying of the product under the sun.
Conduction	:	Transfer of heat with contact particle to particle.
Blanching	:	Partial pre-treatment in which vegetables are heated in water or live steam to inactivate enzyme before processing.
Sulphuring	:	Exposing the of fruits to the fumes of burning sulphure inside a closed chamber.
In-package desiccant	:	Packaging of the dried products with a material like calcium oxide or slica gel.
Sorption isotherms	:	water sorption isotherms is a graphical presentation of data which shows the water relationship of food.
Concentration	:	Removal of water from foods mostly by heat application and concentration of soluble solids or solutes.

Preservation	:	Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutrients and free from and microbial infection.
ERH	:	Equilibrium Relative Humidity.
Osmotic dehydration	:	Removal of water through a membrane from higher concentration to lower concentration.
Unit operation	:	It is a step in the complete process or a physical change in form or place, for example, peeling, cutting, grading, etc.
Drying ratio	:	Drying ratio is the reciprocal of fresh material to dried material.
Spoilage	:	The food which has been damaged or injured which make the food undesirable for human use.
Rehydration ratio	:	Reconstitution ratio is the quantity of water absorbed by dehydrated foods.
Reverse osmosis	:	Reverse osmosis means movement of water through the membrane by applying pressure on the solute side of the membrane in excesses of the osmotic pressure.

14.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Drying of commodity in the sun with non conventional sources of energy like sun and wind.
   - Drying the commodity under controlled conditions like temperature, relative humidity and air flow.

2. Your answer should include the following points:

   - To reduce the weight and bulk
   - To reduce the water activity

3. Your answer should include the following points:

   - Transfer of heat through conduction
   - Transfer of heat through convection
   - Transfer of heat through radiation

4. Your answer should include the following points:

   - Transfer of vapour from product surface to the air
   - Transfer of heat from air to the product surface

5. Your answer should include the following points:

   - By addition of thermal energy to the product
   - By transfer the heat to the product and water surface

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Transport cost less
   - Storage cost less
   - Shipping cost less

2. Your answer should include the following points:

   - Bette quality of finished product
   - Carry out through out the year
   - High yield of the product

3. Your answer should include the following points:

   - They can fit into any size
   - They can fit into any shape
   - They can fit into any forms
   - Low disposal and pollution

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Temperature and RH
   - Product size and surface area
   - Air velocity and dryness of the air

2. Your answer should include the following points:

   - To get heat in
   - To let out mass out

3. Your answer should include the following points:

   - Provides the driving force for moisture removal
   - Carry away the water driven in the form of water vapour

4. Your answer should include the following points:

   - Provide more surface in contact with heating medium
   - Provide moisture surface for moisture removal

5. Your answer should include the following points:
   - To reduces the travelling distance through which moisture is travel from the centre of the product.
   - To reduces the travel distance through which heat transfer from the surface to the centre.
6. Your answer should include the following points:
   - To facilitate mass transfer
   - To speedup drying rate
7. Your answer should include the following points:
   - To form fine cracks in the skin
   - To facilitate drying
8. Your answer should include the following points:
   - To inactivate enzyme
   - To reduce the drying time

Check Your Progress Exercise 4

1. Your answer should include the following points:
   - T constant rate the moisture same as critical moisture
   - At falling rate the moisture is below the critical moisture
2. Your answer should include the following points:
   - Drying means as drying the produce under the influence of conventional energy source like sun and wind, below a certain level of moisture, at which enzymes activity is nil.
   - Reconstitution ratio is expressed on a dry basis i.e. ratio of water content to dry mater.
3. Your answer should include the following points:
   - Optimum ratio of dried material and water/sugar solution
   - Time and temperature of the water/sugar solution
   - Shaking if necessary

Check Your Progress Exercise 5

1. Your answer should include the following points:
   - Water activity (a_w) is defined as the vapour on the aqueous solution to that of pure water at the same temperature.
2. Your answer should include the following points:
   - Uniform automatic feeding
   - Zone heat collection of dried product
   - Continuous operation
3. Your answer should include the following points:
   - High drying intensity
   - Uniform and closely controllable temperature
   - Operation and maintenance simple

4. Your answer should include the following points:
   - Regulating degree of vacuum intensity
   - Regulating heat input intensity

Check Your Progress Exercise 6

1. Your answer should include the following points:
   - Provide a barrier between food and environment
   - Control light transmission
   - Control transfer of heat and gas
   - Control the movement of microorganisms and insect.
2. Your answer should include the following points:
   - The optimum temperature 32°C
   - The optimum RH 55%.

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UNIT 15 FREEZING

Structure

15.0 OBJECTIVES

After reading this unit, you should be able to:

- basic principle of freezing preservation;
- importance of freezing;
- methods of freezing, packaging and storage; and
- maintaining quality in frozen foods.

15.1 INTRODUCTION

In the present chapter we will study about a technology that uses low temperature to preserve food products. You might have noticed that in majority of the preservation methods heat is often used to kill or inactivate microorganisms to extend the shelf life of foods. Subjecting the food materials to low temperature is yet another alternate method to preserve foods. Raw plant material is normally considered to unclean. This is because any raw plant or animal food may be assumed to contain a variety of bacteria, yeasts and moulds. These microorganisms constitute the surface microflora and they need optimum conditions to bring about undesirable changes in the food. Each microorganism present has an optimal, or best, temperature for growth and minimal temperature below, which it cannot multiply. As the temperature drops below this optimal temperature towards the minimal, the rate of growth of the organisms decreases and is slowest at the minimal temperature. The enzymatic reactions in foods also take place at optimum temperatures. If you lower the temperature the enzymatic reactions are also lowered and foods can be prevented from spoilage. This is the basic principle behind freezing preservation of foods.

Do you know what are basic principles of food preservation. I am sure you must have gone through them in other chapters. Let me refresh your memory. Basically there are three methods of preservation. Their main aim is to control the activities of microorganisms. In short you can also refer to them as 3K's. They are 1) Keep them away 2) Kill them 3) Keep them away from growing

The first K refers to use of asepsis methods to keep the microorganism away. The second K refers to killing pathogenic microorganisms to prevent spoilage. Finally the third K employs methods that create conditions which prevent or retard the growth of nonpathogenic type of microorganisms. The Freezing technology is based on the third principle of preservation. Low temperature retards the biochemical reactions occurring in foods and prevents biochemical reactions in food. Microorganisms also get inactivated at low temperature.

15.2 THE FREEZING POINT OF FOODS

Living cells contain much water, often two-thirds of more of their weight. In this medium there are organic and inorganic substances, including salts and sugars and acids in aqueous solutions, and more complex organic molecules, such as proteins which are colloidal suspension. Thus more the salt, sugar, minerals and proteins in a solution. The lower its freezing point (depression of freezing point) and the longer it will take to freeze when put in freezing chamber. If water and fruit juice for example are placed in a freezer, the water will freeze first. Further unless the temperature is considerably below freezing point of pure water, the juice will never freeze completely but rather will become icy and slushy. That is why most of the foods freeze at temperatures between 0-3°C. The temperature of the food undergoing freezing remains relatively constant until the food is mostly frozen, after which time the temperature approaches that of freezing medium. The freezing process is thus a process of lowering of the product temperature from its original value to the storage temperature. From each point, the heat must be removed by conduction to the surface of food. The surface heat is then removed to the refrigeration medium. The freezing time depends upon number of factors such as dimensions, shape of product, thermal properties, temperature of refrigerant medium.

Frozen foods have an excellent safety records and freezing has never been reported to be cause of food poisoning. The great advantage is that microorganisms do not grow in foods when the temperature is –10°C or colder. Foods preserved by means of other preservation methods (chilling, drying, canning) have been more or less directly involved in food safety problems because these foods are stored at temperatures that allow microbial growth.

Freezing has long been established as an excellent method of preserving high quality in food products. Generally freezing preserves taste, texture and nutritional value of foods better than any other preservation method. When done, properly it is the most satisfactory method of preserving many fruits and vegetables. More over the original flavour, colour, texture, and nutritive value is usually retained during freezing in comparison to other methods of freezing. Freezing, however does not, add anything to the original qualities of fresh fruits and vegetables. Therefore, for the highest quality frozen foods, they must be of highest quality in their fresh state, and well-tested ways of preparing them for freezing must be carefully followed. Frozen foods are considered as healthy. Recently, U.S. Food and Drug Administration's (FDA) petition on March 25, 1998 approved an American frozen food industry petition to allow frozen produce to be labelled as "healthy," The nutrient profiles of selected raw fruits and vegetables and frozen, of the same fruits and vegetables revealed relatively equivalent nutrient profiles. In fact, some data showed that the nutrient content level for certain nutrients was higher in the frozen version of the food than in the raw version of the food. In fact most fruits and vegetables during transportation or during retail storage undergo severe depletion of nutrients and essential vitamins. These losses can be prevented if they are frozen soon after they are harvested.

Before actually we see freezing let us understand the meaning of some terms which are often used while describing aspects of low temperature storage and are often are loosely defined. The common terms are Cool Storage, Refrigeration and Freezing. Let us see what is the difference between each other.

Difference between cool storage, refrigeration and freezing

	Cool storage	**Refrigeration**	**Freezing**	**Freezer storage**
Temperature	16 to –2°C	4.5-7°C	-2°C to lower	–18°C
Microorganism	Spoilage microorganisms can grow rapidly at temp. >10°C. Some grow below 0°C if water is unfrozen.	Pathogenic microorganisms grow slowly. Psychotrophic microorganisms grew.	No significant growth of spoilage or pathogenic microorganism. However, multiplication of microorganisms can take place if food is thawed.	

Frozen foods offer various advantages and disadvantages. Let us now see what are they.

15.3 ADVANTAGES OF FROZEN FRUITS AND VEGETABLES

1. The fresh vegetables and fruits closely resemble their frozen counterparts in freshness, since the metabolic activities are arrested to such an extent that all the enzymes are inactivated and microorganisms are under control.

2. The taste, flavour and colour of fruits and vegetables are preserved to a maximum.
3. They have high nutritive value since the retention of nutrients is maximum.
4. Since frozen vegetables have already been subjected to a heat treatment they require less time for cooking thus saves considerable time in kitchen and also saves fuel.
5. Greater convenience in handling and preparation.
6. Freezing is a suitable choice for preserving fruit juices containing anthocyanin and carotenoid pigments since the retention of pigments is maximum.
7. They offer more hygienic food
8. Cent percent edible portion of food of food in each package
9. Since the degradative effect of heat treatment is bypassed in this, the method of freezing can retain the pigment of such fruit juices and concentrates in its best form
10. Freezing can also serve as an intermittent technology for preserving commodities in bulk and supplying in a different form when demand arises eg peas can be frozen in bulk quantities and during demand defrosted put in a brine solution packed in flexible pouches and circulated in market whenever required.
11. Value for money especially off-season
12. No pollution problem in consuming areas
13. The waste collected during freezing can be utilized for production of value added products.

Limitations

1. Some water soluble nutrients may be lost during freezing as the process involves blanching in boiling water.
2. Users of quick frozen foods need to invest on freezers to maintain the quality of the product till used. This adds to the cost of the product.
3. Proper freezing transport facilities have to be developed for each product.
4. Quick freezing can be handled at the industrial level because it involves specialized freezing equipment, technological know-how, strict quality control which would not be feasible on a small scale.
5. Sales markets have to be established in all markets with refrigerated display cabinets.

15.4 QUICK AND SLOW FREEZING

During freezing process the product temperature is lowered and most water is transferred into ice crystals. With decreasing temperature the liquid phase becomes more and more concentrated. As the volume of ice is about 10% larger than volume of water, internal pressure of food may rise to 10 bar or more. This pressure is sufficiently high to cause undesirable textural changes in foods but not as high as necessary to inactivate microorganisms. The size of ice crystal may vary with method of freezing i.e. quick freezing or slow freezing. Quick freezing is defined as the process where the temperature of the food passes through the zone of ice crystal formation in 10 minutes or less. The process removes quick removal of water and small ice crystals are formed in it. Whereas slow freezing involves slow removal of water and process may take 3-72 hours. This also involves ice crystal formation which have more damaging effect on the texture. The advantages of quick freezing over slow freezing are that 1) smaller ice crystal are formed hence there is less mechanical destruction of intact cells of the food; 2) there is shorter period of solidfication and therefore less time for diffusion of soluble materials and for separation of ice; 3) there is more prompt prevention of microbial growth; 4) there is more rapid slowing down of enzyme action. Quick frozen foods therefore are supposed to thaw to a condition more like that of the original food than slow-frozen foods.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Freezing is considered best method of preservation why?

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2. Frozen foods are healthy. Substantiate the statement.

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3. What is the difference between refrigerated storage and frozen storage?

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4. Which will freeze first at 0°C water or juice and why?

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5. What is slow and quick freezing?

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6. Point out main differences between quick and slow freezing.

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15.5 PRE-TREATMENTS PRIOR TO FREEZING

Fruit and vegetable pieces which need to be frozen must preserve their natural colour, flavour and texture and be free from antioxidants or other additives. This is especially required for high moisture product ingredients such as fruit salads or ice-creams. Apart from maintaining sensory properties they should also retain nutritive properties. Chemical and physical action of freezing are highly detrimental to fruit and vegetables, since their texture is mainly ensured by turgor pressure or turgescence (the ability to retain water inside the cells). Rupture of cell wall due to growth of ice crystals and/or enzymatic action during freezing causes loss of shape and prevents its return to the initial state. Loss of shape causes increased drip loss during thawing and a less defined texture. Water is an important molecule involved in deterioration reaction, during freezing and freezing storage. Water within food, migrates towards cold outer surface and then evaporates re-crystallizing as ice. Food surface becomes dry and colour fades. Water may also participate directly in deterioration reactions which involve changes in colour due to enzymatic or non-enzymatic reaction on pigments and production of off-flavour. To minimize such changes in food products, it is important to use certain pre-freeze treatments prior to freezing. These treatments reduce detrimental changes by inactivating the deterioration reactions and by reducing the water content in the material. Common pre-treatments used prior to freezing include washing, blanching, soaking and packaging. Let us now study these pre-treatments one by one.

15.5.1 Blanching

Blanching is a common heat pre-treatment commonly used for most vegetables that are to be frozen and ultimately cooked before use. The aim of blanching is to inactivate enzymes responsible for deterioration in food. Inactivation is achieved by denaturing the proteins that would otherwise take part in reactions leading to deterioration. However, there are also certain disadvantages of blanching:

1. Cellular tissues are affected by high temperature.
2. Loss of texture and an increased risk of microbial contamination due to removal of foods natural microbial flora.

This can however be overcome by using improved blanching treatments employing high temperature short time (HTST) exposure rather than low temperature long time (LTLT).

Lets us now see what are different blanching methods:

1. Immersion
2. Steaming

Immersion

Immersion blanching refers to blanching by directly immersing the food particles in boiling water. This treatment has number of advantages and disadvantages. Sometimes certain additives may be used in blanching water to complement blanching. For instances, addition of citric acid (0.5%) to immersion bath decreases pH. Addition of bisulfite (0.5%) prevents mushroom browning and yellowing of cauliflower. Blanching is quickly followed by a cooling stage. This is done by cooling the product under cool water to bring down its temperature. Rapid cooling avoids microbial growth on the exposed surfaces.

Steaming

Blanching by steaming has the advantage of minimizing the leaching out of soluble materials. However, at the same operating temperature, steam blanching takes 20-40% longer than immersion blanching because of poor thermal exchange.

15.5.2 Dehydro-Freezing

Sometimes depending upon the type of food, and its final use of product, some moisture is removed from the food. This is partial dehydration. Partial dehydration is generally achieved by air drying. The process is also called dehydro-freezing i.e. dehydration prior to freezing. It offers many advantages over conventional freezing:

1. Saves energy
2. Better quality and stability

For partial air drying, selection of food ingredient is very important. The food ingredient selected should be of high water activity (aw > 0.98), since water removal is limited to 50-60% of the original content. To avoid browning, blanching or other treatments such as dipping in antioxidant solution (ascorbic or citric acid, sulphur dioxide) can be used. The air dehydration step usually produces a weight loss up to 50%.

Apple, pear, peach and strawberry are commonly dried by air drying. Partial water removal from the food leads to the concentration of cytoplasmic components within the cells, and to the depression of the freezing point. However, there are certain disadvantages associated with such drying:

1. Free flow of the product is hindered due to particle agglomeration
2. Colour is affected.

For example, kiwi and strawberry fruits are susceptible to heat modifications. For such fruits, air drying must be replaced by osmotic dehydration, which is more effective even at room temperature and which operates away from oxygen.

15.5.3 Osmotic Dehydration

Conventional air-drying can be substituted by or combined with osmotic dehydration as a pre-freezer treatment. The process involves placing the solid food (whole or in pieces) into solutions of high sugar or salt concentration. Usually sucrose, corn starch syrup have been used as osmotic solutions. The principle behind osmotic dehydration is the same as that of osmosis. Placing the food pieces in high osmotic solution leads to ex-osmosis and concentration of the cytoplasmic content.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why are pre-freeze treatments required prior to freezing?

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2. What is blanching? Why it is necessary to blanch fruits and vegetables.

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3. What are advantages of osmotic dehydration over air-drying as pre-treatment prior to freezing?

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15.6 FREEZING TECHNOLOGY

After pre-treatments the material is subjected to the freezing step. Fruits and vegetables (F&V) can be frozen by various methods.

15.6.1 Air or Still Freezing

Air freezing is the oldest of the freezing methods. The equipment is the simplest. The food is simply placed in an insulated cold room at a temperature maintained in the range of –23°C to 30°C. This method is different from the air-blast freezing, which employs air velocities. Although there is some air movement by natural convection, in some cases gentle air movement is promoted by placing circulating fans in the room. This method is also referred as *still air freezing* or *sharp freezing*. It is similar to the freezing conditions that exist in home freezers except that temperatures are low i.e. –18 to –30°C.

15.6.2 Air-Blast Freezing

These freezers operate at temperatures of –30 to –45°C, with forced air velocities of 10-15 m/sec. Food is frozen as batch to tunnels through which carts or belts may be moved continuously. Particulate unpackaged foods, such as loose vegetables are fed onto the moving belt when speed is adjustable according to the required freezing time. In other designs, food moves on trays, in a vertical direction. Trays of particulate products such as peas or beans automatically move upward through a cold air blast.

Today, along with foods frozen as a single block in package, vegetables and other particulate items are frozen individually. This technology is called individually quick frozen or IQF. The freezing process allows the formation of small crystals of ice inside the cell of the product, in order to avoid cellular damage. Therefore when the product unfreezes, there is no spill out of the cellular fluids, warranting the nutritive value, texture and flavour of the product. The particulate items are frozen individually, so they can be poured from a bag for greater convenience. Since, there is some tendency for such particulates to stick together during freezing, product is mechanically dislodged from trays and passed through a beaker device to disaggregate to large clusters. Its major advantage is that you need not unfreeze all the product, only the required quantity be taken out and thawed. Did you know that Safal peas marketed by NDDB are IQF.

The air flow is normally counter-current air flow to bring the coldest air into contact with the already frozen product, and there is no tendency for product to rise in temperature and partially thaw through the freezing process. Normally, in concurrent system, coldest air enters the unfrozen products and tends to rise in temperature through the tunnel as product gives up heat and freezes. Whenever unwrapped food is placed in a cold zone, there is tendency for the food to lose moisture, after the food is frozen.

In freezer, this can have two consequences: 1) Frosting over of refrigerated coils or plates, necessitating frequent defrosting to maintain heat exchanger efficiency, and 2) Drying out of food at surface resulting in defect called **freeze burn**. The food shows brownish colouration at surface and nutrient losses are high. Rates of freeze burn is high in accelerated blast freezers where air is moving at high velocity. To minimize freeze burns, 2 techniques are employed:

1. Pre-chilling food with air of high RH at about –4°C. Because of high humidity, there is a minimum moisture loss. The food then moves into second colder zone when it is quickly frozen. This rapid finish-freezing provides minimum time for the already cold product to lose more moisture, which also decreases the defrosting requirement on freezer coils.

2. Second technique is to wet the unpackaged food pieces in pre-chilling zone so to freeze a thin ice glaze around each food piece.

15.6.3 Fluidized Bed Freezing

In various air-type freezers, cold air is blown up through a wire mesh belt that supports and conveys the product. This imparts a slight vibratory motion to food particles, which accelerates freezing rate. When the air velocity is increased to the point where it exceeds the velocity of free-fall of the particle, fluidization occurs; this is called *fluidized-bed freezing*. This motion not only subdivides the product and provides intimate contacts of each particle with cold air, but keeps clusters from freezing together.

15.6.4 Continuous Type Fluidized-Bed Freezer

Particulate foods are fed by a shaker onto a porous trough. The food is pre-chilled and high velocity refrigerated air fluidizes the product, freezes it and moves it in continuous flow for collection and packaging.

An interesting feature of this unit is continuous and automatic defrosting. Air is blown via fan through cooling coils and up through the porous food trough. Cold air tends to condense its moisture onto cooling coils. A spray of propylene glycol antifreeze is maintained over cooling coils to melt ice as it would be formed. In this way, cooling coils are maintained at maximum operating efficiency.

15.6.5 Indirect Contact Freezing

Indirect contact freezing is based on the principle of placing the food on plates, trays, belts or cold walls so that it is in indirect contact with the cold wall. The food, usually as flat packages, is placed between shelves and there is provision after loading for applying pressure to squeeze the shelves into more intimate contact with the top and bottom of the packages for faster freezing. All is enclosed within an insulated cabinet. The efficiency of freezing depends on the extent of contact between the plates and the food. For this reason, packages should be well filled or slightly over-filled to make good pressure contact with the plates.

15.6.6 Immersion Freezing

Immersing the food directly in a refrigerant other than cold air is called immersion-freezing. It has the following advantages:

1. There is intimate contact between the food or package and the refrigerant, therefore, resistance to heat transfer is minimized.

2. Although loose food pieces can be frozen individually by immersion freezing and air freezing, immersion freezing minimizes their contact with air during freezing, which can be desirable for foods sensitive to oxidation.

For direct immersion freezing, the refrigerant used must have the following properties:

1. It should be Non-toxic.
2. It should be Clean.
3. Free from frozen tastes, odour/bleaching agents.

There are two types of refrigerants for immersion freezing:

1. Low-freezing point liquids: They are chilled by indirect contact with another refrigerant e.g., solutions of sugars, sodium chloride and glycerol.

2. Cryogenic liquids such as compressed liquefied nitrogen, which owe their cooling effects to their own evaporation.

15.6.7 Immersion Chilling and Freezing (ICF) in a Concentrated Aqueous Solution

A third technique ICF is quite similar to osmotic dehydration, in that both involve direct contact between food pieces and a concentrated solution. However, ICF is carried at low temperature ranging from –20°C to 0°C, whereas in case of osmotic dehydration, the temperatures range from +30°C to 80°C. The characteristics of the dissolved solutes determine the extent in temperature to which the solution remains in the liquid state.

Advantages

1. Rapid heat transfer.
2. Individualized freezing.
3. Lower operating and investment costs.

Because of low operating temperatures, and the freezing process occurring inside the food during ICF, mass transfer rates are much lower than in osmotic dehydration ranging from 1 to 7% water loss and 0.5 to 1% solute gain.

However, in spite of its potentialities, ICF process has been developed little on an industrial scale, because of an inadequate control of mass transfer (water and solutes) between the product and the refrigerating solution. The freezing time depends upon (1) Dimension and shape of product, (2) thermal properties, (3) initial and final temperature, and (4) temperature of the refrigeration medium.

15.6.8 Immersion Freezing with Cryogenic Liquids

Cryogenic liquids are liquefied gases of extremely low boiling point such as liquid nitrogen and liquid carbon dioxide, with boiling point of –196°C and

–79°C respectively. Although liquid nitrogen is capable of freezing food down to –196°C, this is virtually never done, because it entails unnecessary cost and could even be damaging to some foods. The food is seldom frozen to a temperature below –45°C and quality results largely from the speed at which the temperature is reached. In most of the cases of fruits, vegetables, meat and fish items, it may take 1-3 minutes. Major advantages of liquid nitrogen freezing are as follows:

1. It undergoes slow boiling at –196°C, this provides great driving force for heat transfer.

2. Liquid nitrogen, like other immersion fluids, intimately contacts all portions of irregularly shaped foods, thus, minimizing resistance to heat transfer.

3. No primary refrigerant is required to cool this medium, since low temperature results from the evaporation of liquid nitrogen.

4. Liquid nitrogen is non-toxic and that to food constituents. Moreover, it can displace air from food and thus minimize oxidative changes during freezing and through packaged storage.

High quality frozen foods are produced because of high speed of liquid-nitrogen freezing. High cost of liquid nitrogen remains to be its major limitation. Liquid nitrogen is manufactured by comprising air and simultaneously removing the heat of compression. The cooled compressed air is then allowed to expand through specially designed valves. This expansion causes further chilling.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List some factors affecting the rate of freezing.

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2. List some important commercial freezing methods.

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3. What is cryogenic freezing? Why is the quality produced by cryogenic freezing the best?

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4. What is the difference between still air sharp freezing and air-blast freezing?

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5. What is IQF? What are its major advantages?

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6. What is freeze burn? Which food items are highly susceptible to freeze burn? How can you minimize this effect?

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15.7 PACKAGING AND STORAGE

A wide variety of materials have been used for packaging of frozen foods including plastics, metals and paperboards. Polyethylene (PE), low density Polyethylene(LDPE) and High density Polyethylene (HDPE) are commonly used for packaging of IQF foods i.e. fruits, vegetables and fish. Materials are easy to seal and can be easily printed. LDPE is also easily available and cheap. HDPE can tolerate temperature in excess to 100°C. Both HDPE and LDPE however provide relatively poor barrier protection from oxygen. Polyester tetraphthalate (PET) is another common material used. The trays of the material are suitable for reheating in conventional and microwave oven with stability at temperature in excess of 250°C. However the materials are expensive and can become brittle at freezer temperature. Polystrene (PS) is also general plastic material used for frozen food applications. Commercial storage of frozen storage of frozen products is usually done in deep freezers at –18 to –20°C.

15.8 QUALITY AND PHYSICAL CHANGES IN FROZEN FOODS

When the food is frozen it undergoes number of quality and physical changes. Lets us see what they are.

15.8.1 Concentration Effects

We have already seen that during freezing concentration of solutes take place. Damage due to concentration results in

1. Gritty, sandy texture of food due to precipitation of solutes out of solution.
2. Salting out at proteins effect due to solutes remaining in concentrated solution.
3. Drop in pH drop causing proteins to coagulate.
4. Gases in solution are also concentrated. This can cause super-saturation of gases and ultimately force them out of solution. Frozen beer or soda pop may have such a defect.

15.8.2 Ice Formation: Nucleation and Crystallization

The freezing process includes 2 main stages first is the formation of ice crystals which is termed as nucleation and subsequently crystallization or increase in crystal size. Nucleation is nothing but combining of molecules into an ordered particle of sufficient size to serve as a site for further crystal growth. It is important for freezing to initiate. When the temperature falls below 0°C, viscosity increases and nucleation stops. Now crystals start growing. Before we understand how ice-crystals are formed, it is important to understand the type of fluids in the cells. There are 2 types of fluids viz., Extra-cellular fluid (EF) and Intracellular fluid (IF). The concentration of salts and other soluble products is higher within the cells than outside. The cell membrane acts as osmotic barrier and maintains the difference in concentration. When the product is frozen, the first ice-crystals are formed outside the cells, since the freezing point is higher. The cells lose water by diffusion through the membrane and the water will crystallize to ice on the surface of the crystals already formed in the extra-cellular space. As the cells lose water, the remaining solution within the cell becomes more concentrated and their volumes shrink causing the cell wall to collapse. The large ice-crystals formed outside the cell wall occupy a larger volume than the corresponding amount of water and therefore, will execute a physical pressure on the cell wall. When the pressure becomes high, it can damage the cell wall and lead to release of intracellular fluid (Drip loss). If the freezing rate is high, ice-crystals are formed outside the cells. Only at a very high freezing rates, small crystals are formed uniformly throughout the tissue, both externally and internally with regard to the cells.

15.8.3 Freeze Cracking

Generally, light freezing rates lead to small ice crystals and to better quality food systems. However, some products may crack when submitted to high freezing rates as in cryogenic fluids. This is particularly seen in mango slices frozen by liquid nitrogen. Pre-cooling prevents freeze cracking.

15.8.4 Moisture Loss

Moisture loss, or ice crystals evaporating from the surface area of a product, produces freezer burn. We have already discussed what freezer burn is. This surface freeze-dried area is very likely to develop off flavours. Packaging in heavyweight, moisture-proof packaging material will prevent freezer burn.

15.8.5 Drip Loss

Formation of ice crystals causes a physical pressure on the cell wall. When the pressure becomes high, it can damage the cell wall and lead to release of intracellular fluid. This is called drip loss.

15.8.6 Rancid Flavour

Another group of chemical changes that can take place in frozen products is the development of rancid oxidative flavours through contact of the frozen product with air. This problem can be controlled by using a wrapping material which does not permit air to pass into the product. It is also advisable to remove as much air as possible from the freezer bag or container to reduce the amount of air in contact with the product.

The winning strategy of frozen good industry is to continually improve quality.

Here is a list of some tips to produce quality frozen products:

1. High quality raw material containing high level of vitamins (especially water-soluble ones, like vitamin C) and minerals to ensure that after pretreatments such as blanching the nutritional value remains high. Colour, flavour and texture are yet other factors affecting quality. Peas is an good example of the cultivar affect and harvesting period on the quality of frozen product. Consumers and the frozen industry prefer sweet and tender varieties with small seeds which are completely different from what is required by the canning industry and the fresh market.

   When peas are ripening, their sweetness is due to the sugars (about 6%) and to the low starch content (1%). Immediately after harvesting there is a rapid reaction conversion of sugar into starch which can exceed 4%. This reaction determines a gradual reduction of sweetness, an increase infirmness and sensation in mealiness.

2. Interval between harvesting and freezing Fruits and vegetables undergo fast changes in chemical composition, sensory attributes and nutritional value. The product should be processed as quickly as possible e.g., peas and spinach have intense metabolism (high respiration rate after processing) which means severe decrease in quality if the time between harvesting and processing is too long. By using quick refrigeration, these negative phenomena can be stopped.

15.9 STORAGE AND TRANSPORTATION OF FROZEN PRODUCE

To preserve quality and safety in frozen foods, strict temperature requirements are must during storage, handling, distribution, retail display and consumer storage. It is recommended that food temperatures are maintained at –18°C or colder, although exceptions for brief periods are allowed during transportation or local distribution when –15°C is permitted. Also, retail display cabinets should be at –18°C, to an extent consistent with good storage practice, but not warmer than–12°C. The transport and distribution sections of the chill chain are particularly important to control in order to ensure both safety and quality. It is important to check temperature of foods at each point within the chill chain from storage and transportation.

15.10 FUTURE TRENDS IN FROZEN FOODS

Demand for frozen foods will grow

Growth of corporate cultures, dual incomes, western life styles and need for convenience are likely to lead to growth of this sector. Changing life styles are increasing both the consumption of convenient food products and eating out habits. In the food service sector and fast food chains, reliance on frozen food is greater because they offer the ability to control supply with variable demands. The frozen food consumption is bound to increase in India too. Consumers today view adoption of western life styles as index of progress. In near future, we should not therefore be surprised to see increased consumption of western style convenience foods as the amount of time available to women has been substantially decreasing. Certainly, we are already seeing the major food multi-functional giants, such as MAC Donalds', Pizza Hut, Dominos investing in these future markets.

Frozen foods will be more nutritious

The frozen food industry is in best position to deliver healthy products to the consumers. Careful selection of ingredients, superior genotypes, good formulation and processing and a well controlled frozen food chain have the ability to deliver products much closer to their original nutritional content than can possibly be achieved through the chilled chain wherever rapid deterioration is inevitable.

Anti-freeze proteins

An area of research that has caused great excitement in the scientific community and increasingly in the frozen food industry is the field of antifreeze proteins (AFP). These proteins were first discovered in Antarctic and Arctic fish species. The freezing point of sea water is –2°C. The freezing point of fish serum is –1°C. These proteins allow fish to survive below their melting point without freezing. AFP's have been extracted and identified in grasses such as polar fish, winter rye, in carrots and in a number of insects. These proteins can affect freezing by lowering freezing temperature and retarding recrystallization. Claims for AFP have been made from many food plant materials including carrots and brussel sprouts. Such discoveries have begun to show a possible future for AFP in food industry. We can see the potential of transforming plants (transgenic which can express AFP and therefore expected to have a greater resistance to re-crystallization damage during distribution with the resultant effect of increased textural quality and retention of nutrients on thawing.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are anti-freeze proteins?

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2. What type of packaging material is most suitable for freezing vegetables?

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15.11 LET US SUM UP

Among processing methods freezing is the best method as it results in quality product with high retention of nutrients. Quality of frozen foods can be constantly improved and maintained by selecting the right kind of fruit or vegetable, its right cultivar, pre-freezing treatment and technology. Storage at low temperature is important to maintain quality.

15.12 KEY WORDS

Freezing point	:	Temperature at which the liquid congeals into the solid state at a given pressure and temperature.
Refrigerated storage	:	Refers to storage temperatures above freezing point of water i.e. about 16 to –2°C.
Quick freezing	:	Quick freezing is defined as the process where the temperature of the food passes through the zone of ice crystal formation in 10 minutes or less. The process removes quick removal of water and small ice crystals are formed in the process.
Slow freezing	:	Slow freezing involves slow removal of water and process may take 3-72 hours.
Fluidized bed freezing	:	A method of freezing used for particulate items such as peas, diced carrots, corn and berries. The freezer employs a bed with a perforated bottom through which refrigerated air is blown vertically upwards.
Blanching	:	Blanching is a common heat pre-treatment commonly used before processing most vegetables. The main aim is to inactivate enzymes responsible for deterioration in food.
Sublimation	:	The change of state from ice to water vapour or water vapour to ice. Unpackaged frozen material changes to gaseous form e.g. dry ice(frozen carbon dioxide)when exposed to extreme cold air.
Dehydro freezing	:	Is pre-treatment given prior to freezing, involving partial removal of water
Individual quick freezing	:	Is the latest advanced technology for freezing particulate vegetable items. The product is frozen individually and helps in
Freeze burn	:	It refers to a defect which develops during frozen storage. Moisture loss due to sublimation from surface leads to discolouration in form of patches of light coloured tissues. This can be controlled by humidification or lowering of storage temperature or better packaging.
Antifreeze	:	Chemical substances that added to a liquid to lower its freezing point. These chemicals prevent freezing and are commonly used in coolants for aeroplanes and automobiles.

15.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   Freezing is considered best method of preservation because,

   - It preserves colour, taste, texture and nutritional value of foods better than any other preservation method.
   - Frozen foods have an excellent safety record and freezing has never been reported to be cause of food poisoning.

2. Your answer should include the following points:

   Have nutrient profiles higher or equal to raw food, e.g., freshly harvested fruit and vegetables may loose considerable amount of nutrients during transportation and retail outlet, but freshly harvested frozen foods retain most of nutrients

3. Your answer should include the following points:

   Refrigerated storage refers to storage temperature above freezing. Generally the temperature is maintained at 16 to -2°C. Commercial and household refrigerators operate at 4.5 to 7°C. Frozen storage however refers to storage temperature below –18°C.

4. Your answer should include the following points:

   At 0°C, water will freeze first than fruit juice because water is a pure fluid, whereas, juice has many dissolved organic or inorganic substances including salts, sugar and acids in the aqueous solution. Apart from this there are also proteins and colloidal suspensions. They cause a depression of freezing point, thus, to freeze juice, lower than 0°C temperature is employed.

5. Your answer should include the following points:

   Quick freezing: It is defined as the process where the food passes through the zone of maximum ice crystal formation in 10 minutes or less, whereas, in slow freezing the process may take 3-72 hrs depending upon the commodity.

6. Your answer should include the following points:

   Main differences between quick and slow freezing are:

Quick freezing	**Slow freezing**
The process involves quick removal of water, may take 10 min.	The process involves slow removal of water, may take 3-72 hrs.
Small ice-crystals are formed which maintain the textural integrity of cell.	Large ice-crystals are formed which seriously affect the cell texture.
Prompt prevention of microbial growth.	Slow prevention of microbial growth.
After thawing the food resembles like that of original food.	After thawing the food is soft and mushy.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   Pre-freeze treatments prior to freezing is mainly given to reduce the water content of cells which thereby

   - Prevents rupture of cells and maintains cell texture
   - Avoids increased drip loss
   - Also avoids changes in colour of food due to enzymatic and non-enzymatic reactions.

2. Your answer should include the following points

   Blanching: It is a common heat pre-treatment used prior to processing (drying, freezing and dehydration). It is necessary to blanch fruits and vegetables prior to freezing in order to inactivate enzymes responsible for deterioration in quality of frozen foods.

3. Your answer should include the following points:

   Advantages of osmotic dehydration over air drying:

   1. Retains better colour.
   2. Prevents particle agglomeration.
   3. Prevents oxidation.
   4. Effective at room temperature.

   Highly suited for fruits such as kiwi and strawberry which are susceptible to heat modification.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   Some factors affecting rate of freezing are:

   - Shape of the product.
   - Kind of the product.
   - Thermal properties of the product.
   - Temperature of the refrigerant medium.

2. Your answer should include the following points:

   Some important commercial freezing methods are:

   1. Air or still freezing.
   2. Air blast freezing.
   3. Fluidized bed freezing.
   4. Continuous type fluidized bed freezer.
   5. Immersion freezing.
   6. Immersion freezing with cryogenic liquid IQF (individual quick freezing is being used for freezing peas.

3. Your answer should include the following points:

   Cryogenic freezing is a freezing process involving liquid nitrogen (–196°C) as the refrigerant medium, is termed as cryogenic freezing. The quality of the food frozen by liquid nitrogen is best because:

   1. Food is quick frozen and takes 1-3 minutes.
   2. It is non-toxic to food constituents and can displace air from food, thus, minimizing oxidative changes during freezing.

4. Your answer should include the following points:

   Difference between still air freezing and air blast freezing:

Still air freezing	**Air blast freezing**
Temperature is maintained at –23 to –30°C.	Temperature is maintained at –30 to –45°C.
Air movement by natural convection.	Air movement with forced air velocity of 10-15 sec.

5. Your answer should include the following points:

   IQF is individual quick freezing. It is the latest technology for freezing particulate food items.

   Advantages:

   1. The particulate items are frozen individually.
   2. Small ice-crystals are formed. Thus, when the product unfreezes, there is no spill out.
   3. High nutritive retention and sensory quality.
   4. Allow greater convenience because only required quantity can be separated from the large cluster and thawed.

6. Your answer should include the following points:

   Drying and discolouration of the food at surface is termed as freeze burn. The food shows brownish discoloration at surface and nutrient losses subsequent to thawing. Frozen fish is most susceptible to freeze burn. The defect can be minimized by

   1. Pre-chilling the food with air of high RH at about –4°C.
   2. Wet the unpackaged food pieces in pre-chilling zone so as to freeze a thin ice glaze around each piece.

Check Your Progress Exercise 4

1. Your answer should include the following points:

   Antifreeze proteins are proteins that when added to a liquid to lower its freezing point. These proteins have been identified and isolated from many cold-tolerant insects and plants. These proteins are of great importance in improving the quality of frozen products.

2. Your answer should include the following points:

   A wide variety of materials have been used for packaging of frozen foods including plastics, metals and paperboards. Polyethylene (PE), low density Polyethylene (LDPE) and High density Polyethylene (HDPE) are commonly used for packaging of frozen foods.

15.14 SOME USEFUL BOOKS

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2. Potter, Norman N. (2000) Food Science. CBS Publishers.

3. Pulle, Mervyn (2003) Food processing insights into Food manufacturing. Food Technology series Part 4, KBS Publishers.

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UNIT 16 CHEMICAL ADDITIVES

Structure

16.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the meaning of a food additive;
- understand the role of additives in food preservation;
- discuss the different permitted preservatives in food industry and their concentrations;
- discuss the various applications of food additives; and
- know the simple low cost, low energy intensive preservation technologies.

16.1 INTRODUCTION

Fruits and vegetables are a major source of important vitamins and minerals. Owing to its vast agro-climatic conditions, India produces almost all types of fruits and vegetables. Being highly perishable, fruits and vegetables have to be preserved and processed for later use. India processes 1.8 per cent of the total fruit and vegetable produce. Chemical preservation of perishable commodities by various food additives forms a major part of the preservation industry which is used in conjunction with other forms of preservation like canning, freezing, dehydration etc.

Food additives as chemical preservatives have been used for centuries to extend shelf life of the variety of food products. Smoke, alcohol, vinegar, oils and spices were used more than 10,000 years ago to preserve foods. They have been used since man first learned to preserve food products from one harvest season to the next to preserve and conserve the food and its nutritional value. The use of salt and smoke for preservation dates back to thousands of years. The Egyptians used colours and flavourings to enhance the appeal of certain foods, while the Romans used saltpeter, spices and colours for preservation and quality improvement. In the past 40 years, developments in food science and technology as well as changes in consumer demand have led to a substantial increase in the use of food additives. This has given consumers a variety of foodstuffs of high and uniform quality at reasonable prices. They play a vital role in today's bountiful and nutritious food supply.

Social changes in this century have caused a rapid evolution of the food supply throughout the world. While a shrinking percentage of the population is engaged in primary food production, we demand more variety than ever before in the food we eat. With a growing percentage of both two-wage and single-parent families, the demand for convenience foods has never been greater. Meeting consumer demands for variety taste and convenience with food products that are at the same time wholesome, safe and affordable, can be achieved using modern food processing technologies including a variety of food additives proven useful and safe through long use and rigorous testing.

16.2 DEFINITION OF CHEMICAL ADDITIVES (FOOD ADDITIVES)

Additive means any substance which is not a normal constituent of the food material and is purposeful addition which is aimed for technological, organoleptic and nutritional reasons. According to the WHO, a food additive is defined as a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging. The term does not include chance contaminants. Food additives have also been defined by the National Academy of Sciences as those chemicals that may be incorporated in foodstuffs, either directly or indirectly during growing, storage or processing of foods.

The Prevention of Food Adulteration Act (PFA) specifies any substance as additive which is not normally consumed as a food itself but used as a typical ingredient of food whether or not it has nutritive value, the intentional addition of which to food for technological reasons including organoleptic purpose during manufacturing, processing, preparation, treatment, packaging, transport or holding of such food results or may be reasonably expected to result in it or its by-products. PFA rules therefore encompass all food and food products in the country and aim at ensuring the consumers get food and food products of satisfactory composition by laying down mandatory quality standards.

16.3 FUNCTIONS OF FOOD ADDITIVES

- To enhance the consumer acceptability.
- To help in maintaining or improving the nutritional quality.
- They should be non-toxic, non-allergic, safe and effective.
- To enhance stability or keeping quality by acting as antimicrobial agents with the resulting reduction in waste and prevention of chemical and biological deterioration.
- To make food more attractive and provide sufficient aids in the food products for improving texture, colour and flavour.

- To check spoilage by inactivating microorganisms and maintain safety of foods.
- To facilitate preparation.
- To improve palatability of the product.

16.4 PERMITTED FOOD ADDITIVES AS PRESERVATIVES

Preservatives are substances when added to food to retard, inhibit or arrest the activity of microorganisms such as fermentation, acidification and decomposition.

16.4.1 Classes of Preservatives

CLASS I

Common salt, sugar, dextrose, spices, vinegar or acetic acid, honey. They are mainly natural products which are used comparatively in higher concentrations than class II preservatives.

CLASS II

They are generally synthetic chemicals used in small quantities. Benzoic acid and its salts, sulphur dioxide and the salts of sulphurous acid, nitrites and nitrates, sorbic acid and its salts, propionic acid and its salts, lactic acid and its salts are used. Potassium metabisulphite is generally used in non-coloured products whereas in coloured products containing anthocyanin pigment, sodium benzoate is used.

16.4.2 Legitimate Uses in Food Processing

Food additives have a legitimate use in the food processing and distribution systems in promoting the utilization of available foods. The use of food additives may be technologically justified when it serves the following purposes:

1. The maintenance of the nutritional quality of a food.
2. The enhancement of keeping quality or stability with resulting reduction in food losses.
3. Making foods attractive to the consumer in a manner which does not lead to deception.
4. Providing essential aids in food processing.

Safety in using an additive is an all important consideration. While it is impossible to establish absolute proof of the non-toxicity of a specified use of an additive for all human beings under all conditions, critically designed animal tests of the physiological, pharmacological and biochemical behaviour of a proposed additive ca provide a reasonable basis for evaluating the safety of use of a food additive at a specified level of intake.

The Food and Drug Administration of the Department of Health, Education and Welfare administers the Federal Food, Drug and Cosmetic Act, in the United States. The federal Food, Drug and Cosmetic Act controls the addition of all additives to food. Chemicals may be incorporated legally in the fabrication of many foods, and many chemicals indeed serve to improve the quality of many foods.

16.5 TYPES OF FOOD ADDITIVES

Of the variety of ways food additive have been classified, most involve functional groupings. Chemical groupings are convenient since they place molecules of similar structure and physical-chemical properties in comparable categories. Toxicological and metabolic studies also may be correlated with chemical groupings. However, compounds of a single chemical family perform different functions in the food industry. Moreover, since chemical structure does impart physical-chemical characteristics, many function classes follow responsible chemical lines; i.e., the enzymes are major classes in either system. The consumer viewpoint is less restricted than is the legal, governmental or scientific; without knowing hows or whys, he wants an attractive product which provides assurance of health. A functional classification is given to place in perspective the specific types. The classification presented in detail below is comparable to, but provides an overall view less well than, this simplified system of user.

16.5.1 Intentional Food Additives

- Nutritive
- Freshness maintenance
- Sensory
- Processing aids

16.5.2 Incidental Food Additives

Many of the 2-3000 chemicals added to food occur in nature. They may be isolated from rich source material and used at will. Some, i.e., enzymes, will never be commercially available from synthetic sources. However, it is more efficient to make most of them in the laboratory. Thus, although some more efficient to make most of them in the laboratory. Thus although some are isolated in relatively pure form from natural sources, most are man made.

Table 16.1: Range of concentration of chemical preservatives permitted in various processed foods are given below:

Preservative	Concentration (ppm)	Food
Sulphur dioxide or salts of sulphurous acid	49-3000	Squashes, fruit pulp, crushes, jams, syrups, beer, pickles, beverages etc.
Propionic acid and its salts	5000	Bread
Benzoic acid and its salts	50-600	Syrups, squashes, jams, jellies, RTS beverages, pickles, chutneys
Sorbic acid	200-3000	Beverages, cakes and icings, cheese, cider, dried fruits, salad dressings, wine, margarine
Nisin	1000	Cheese
Nitrites	200	Cooked pickled meat
Nitrates	500	Cooked pickled meat

Table 16.2: Uses of various food additives

Additive	Use
Preservatives	• Sorbates are used as mould and yeast inhibitor in processed cheese and spreads, salad dressings, dried fruits, yogurt, fermented milks, soft drinks, soup concentrates, wine, cider and cakes. • Propionates are used as mould and rope inhibitors in bread, baked goods and dairy products. • Benzoates are used in beverages, fruit juice, pickles, jams, beer, dessert sauces, marinated fish, coffee essence. • Parabens are used in low acid foods (pH > 5.0) e.g. meat products, fruit juices, pickles, jams, beer, dessert sauces, marinated fish, coffee essence. • Sulfur dioxide and sulfite salts are used in dried fruits, soft drinks, purees, fruit juices, fermentation industry, dessicated coconut, tinned crabmeat, powdered garlic, frozen mushrooms, sausage meat.
Antioxidants	Wine, beer, cider, fruit juices, dried fruits, milk.
Colouring Agents	Confectionery, cake and drinks industries and in dairy sector.
Flavours	Soft drinks, sugar, confectionary, ice cream, soups and jams, biscuit and cake industry.
Texture modifiers	Margarine, salad cream, chocolate, processed milk, ice-cream, jelly and sauces.
Sweeteners	Confectionery, bakery products, soft drinks, jam, jellies, and ice-cream.
Antifoaming agents	Bakery products, meat products, confections, dairy products, beverages, jams and jellies.
Firming agents	Canned vegetables, canned apples, frozen apples and cheese.
Acidulants	Baked goods, beverages, confections and gelatin desserts, dairy products, fruit and vegetable processing and processed meats.
Nitrite	Various meats and cheeses.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How are food additives important in our lives? List a few of them.

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2. Differentiate between Class I and Class II preservatives.

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3. Define the food additives.

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16.6 NUTRITIONAL ADDITIVES

The term nutritional additives can be used to mean the addition of vitamins, minerals, amino acids, fatty acids, as well as other pure chemical compounds to food in order to improve or maintain the nutritional quality of foods. However, manufacturers soon discovered that along with an improvement in nutritional qualities, nutritional additives often provide functional qualities.

Nutritional additives can be used to restore nutrients to levels found in the food before storage, packaging, handling, and processing. An early example of this is the enrichment of grain products, corn meal, and rice. Another use of nutritional additives is to improve the nutritional status or corrected nutritional inferiority in a food that replaces a more traditional nutritional food, an example would be fortification of breakfast drink substitutes with folacin and vitamin C. With the advent of nutritional levelling and increased public interest in nutritional properties of food, the food industry rapidly recognized that the addition of nutritional additives can be a selling point.

Although it is often thought that the major reason to add nutritional additives to a food supply is to provide nutrients and improve dietary status, nutrients are also added for a variety of other purposes. For example, vitamin C and E may be used for antioxidant properties; beta carotene may be used to provide colour. In these cases consumers obtain both functional and nutrient advantage.

Like all additives, nutritional additives are commercially available in an array of forms such as powders, encapsulated in gelatin, emulsified in oil. The form used depends upon the type of application. Nutrition additives are often protected by protective additives such as antioxidants. Two critical factors in the selection of the form of the additive are stability of the vitamin preparation and its miscibility with the intended food matrix.

16.7 THE POTENTIAL USE OF PROBIOTICS

Almost a hundred years have passed since the introduction of theories on the prolongation of life by modulation of intestinal ecosystem. The scientific basis for use of probiotic organisms has only recently been firmly established and some sound clinical studies have been published. The physiological and nutritional properties of selected bacterial strains are well characterized, and it is possible to verify that some strains are “probiotic” with document effects of maintaining and promoting the health of the host when used as part of the daily diet.

Few well-documented probiotic dairy strains are available at present. The most important are listed in Table 16.3. Specific effects of probiotics include, for example, modulation of diarrhea from various causes, relief of lactose intolerance, and constipation. More recent claims with some strains include enhancement of immune functions, vaccine adjuvant effects, reduction of serum cholesterol levels, and changes in colour cancer-related parameters. The immune enhancing effects have been reported in several studies for two strains, *Lactobacillus acidophilus* LCI and *Lactobacillus* GG, which appear to act as immunoadjuvants. Effects on cholesterol levels remain to be verified since so many confounding factors have contributing to varying extents in different population groups. At the moment, no firm proof on any of the probiotic strains of lactic acid bacteria is available, and more well defined clinical work is needed.

The future of research on probiotic bacteria will focus on selecting new, more specific strains for the well being of the host. Different regions of the gastrointestinal tract may be benefiting from different probiotic bacteria and maybe the time has come for disease specific strains. This is particularly true with conditions such as rotavirus diarrhoea and gastritis caused by *Helicobacter pylori*. However, the requirement for good clinical studies will become ever more important. Carefully controlled studies on selected strains could result in the development of probiotic bacteria targeted for specific diseases and their prevention. Mixtures of such organisms may be of general therapeutic value as additives in clinical foods.

Table 16.3: Current probiotic bacteria and their reported effects

Sl. No.	Strain	Reported effects in clinical studies
1.	Lactobacillus acidophilus La-5	Immune enhancer, adjuvant, protection against traveller's diarrhoea; balance intestinal microflora.
2.	Lactobacciullus acidophilus NCFB 1748	Lowering of fecal enzymes, decreasing fecal mutagenicity, prevention of radiotherapy-related diarrhoea.
3.	Streptococcus boulardii	Prevention of antibiotic-associated diarrhoea; treatment of Clostridium difficile diarrhoea.
4.	Lactobacillus johnsonii LA1	Adherence to intestinal cells; balances intestinal microflora; immune enhancement; adjuvant in H. pylori treatment
5.	Lactobacillus casei Shirota	Prevention of intestinal disturbances, balancing intestinal bacteria, lowering fecal enzyme activities, positive effects on superficial bladder cancer.
6.	Streptococcus thermophilus; Lactobacillus bulgaricus	No effect on rotavirus diarrhoea; no immune enhancing effect during rotavirus diarrhoea; no effect on fecal enzymes; strain-dependent improvement of lactose introlerance symptoms.
7.	Bifidobacterium lactis Bb-12	Treatment of viral including rotavirus diarrhoea; balancing intestinal microflora; alleviation of food allergy symptoms.
8.	Lactobacillus reuteri	Shortening of rotavirus diarrhoea; colonizing the intestinal tract.

16.8 BASIS FOR CONCERN

Concern is directed toward synthetic rather than naturally occurring additives. In-home interviews found concern about additives was related to a general fear of chemicals and diseases, specially cancer (Sloan et al, 1986). Consumers believe chemicals present hidden and unknown dangers, which people are powerless to predict (McNutt et al, 1986). Consumer association with chemicals may relate to environmental concerns such as acid rain and toxic waste dumps. Over half of consumers indicated they think there is a connection between chemical spills and their feelings about chemicals in food. Almost 20% of the consumers believe that chemicals are never good for people and over 80% believe that chemicals cause cancer.

Consumers indicated a lack of trust in regulators and regulatory procedures. Both men and women believed that expert opinion was influenced by who paid their salary. Concern was believed justified since some approved additives were later withdrawn later on.

Food allergies may also trigger about additives. In the early 1980s, 26% of U.S. consumers said that they feared an allergic reaction to artificial ingredients, and 22% avoided particular food fearing the food may contain an allergen and avoided such foods. Similarly in Australia, the main concern given for food additives was allergies.

Consumer response to additives may also berelated quality. Over 75% of consumers indicated that artificial flavours give food a poorer taste than natural flavours. Their descriptions of artificial flavouring range from "too salt" to "too sweet" and from "strong tasting" to "flat tasting". Almost 70% of consumers attributed better quality to natural flavours.

Consumers appear unaware of potential benefits from additives. More than 80% of Canadian consumers surveyed in 1978 thought that food colours were unnecessary. They believed that additives made food are less safe. Sloan and co-authors believe that consumers will accept a product if benefits outweigh disadvantages and possible risks are small.

16.9 STEEPING PRESERVATION

Fruits and vegetables can be preserved safely in a chemical solution that checks enzymatic, oxidative and microbial spoilage in the preserved material. The chemical solution makes use of various food additives such as organic acids (glacial acetic acid, citric acid, lactic acid), chemical preservatives (potassium metabisulphite, sodium benzoate) along with salt, sugar, spices etc. in water, which are quite cheap and easily available in the market. Any container (glass, porcelain or glazed earthenware jars) can be used for storing the steeped material. Flow sheet of steeping preservation of fruits and vegetables is as shown below:

Select raw vegetables such as cauliflower, ginger,
lotus stem, carrot, radish and raw mango slices

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Prepare the raw material by peeling, cutting and washing

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Fill the prepared material in clean glass jars

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Prepare chemical solution in potable water using 3%salt, 8% glacial acetic acid
and 0.2% metabisulphite
Fill the chemical solution up to the brim in glass jars
containing fruits and vegetables

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Maintain the ratio of material to solution 1:1.5. Close the

↓

jars tightly and store them in a cool and dry place
Wash vegetables thoroughly before use for culinary purpose.
For pickle, *pakora* and chutney preparations, material
can be used straight away after taking out from the solution

Advantages of Steeped Preserved Products

The steeped preserved products have many advantages:

- The method of preservation is very simple and cheap.
- Compared to canning or bottling where heat sterilization is essential, the vegetable or fruit in this method does not suffer much loss of texture even if it is blanched.
- Sulphur dioxide present in potassium metabisulphite (if added in the solution) helps to retain vitamin C content of the preserved material.
- The method can be used on a commercial scale, at the production centres by using large sized wooden vats coated with wax or wax coated cement tanks, which can be properly sealed.
- This low cost technology can be used for bulk packing in glut season for retail-off season sale in the market.
- Preserved material can be stored for 6-8 months at an ambient temperature and beyond one year, at a low temperature.
- Steeping preservation is used either for preserving the material for packing various products or for curing them for lactic fermentation for the preparation of fermented processed products.

16.10 PRESERVATION OF PULP, JUICES, SAUCES, CHUTNEYS, PUREES AND PASTES

Preservation of Pulps and Juices

Fruit pulps and juices can be preserved by adding 1g KMS and 10g citric acid per kilogram or pulp/juice. There is no need to add citric acid in acidic fruits such as lemon. The citric acid and KMS should be dissolved separately in little amount of water and then added in fruit juices. In coloured fruit juice, i.e. coloured grapes, phalsa and plums etc., sodium benzoate is added instead KMS as the latter bleaches the colour of the product. Preserved pulps and juices can be stored for 6-8 months at room temperature and beyond one year at low temperature. In this method, pulps and juices to be sterlized by heat initially, cool it and then use there preservatives. Similarly, the container used for packing should be reasonably impermeable to air and water vapour.

Preservation of Sauces, Chutneys, Purees and Pastes

Preservatives added for the preparation of pulp, juices, sauces, chutneys, purees and pastes are important constituents of these products. Vinegar, salt and sugar are common preservatives used for preservation of these products. The chemical preservatives such as sodium benzoate and potassium metabisulphite used in commercial scale preparations ensure long term storage by retarding the growth of microorganisms without interfering with the other physico-chemical and sensory characteristics of the preparation. Following are the consideration for the selection of a chemical to be used as a preservative in various food preparation.

- Type of organism to be controlled
- Length and conditions of product storage
- Physical and chemical characteristics of the food

16.11 USE OF CHEMICALS DURING CURING OF PICKLES

Fermented foods have many advantages such as prolonged shelf life, extended seasonal life, less time for cooking and sometimes increased acceptability and digestibility. They also act as laxatives. Vegetables can be preserved by simple lactic acid fermentation which enhances the organoleptic and nutritional quality of the product.

Commercial preservation of many pickle relies upon conversion of carbohydrates to organic acids during bulk storage and/or the addition of sufficient amount of sugar, vinegar and other ingredients to the fully cured and packed products to preclude any microbial growth. Organic acids, oils, salt and spices have antimicrobial properties at suitable concentration. Pickles in brine as such or after fermentation however, need some amount of preservative or pasteurization to prevent the spoilage.

Spices such as garlic, cloves, chillies, mustard seeds, dill herbs etc., have antimicrobial effect. Antibacterial and antifungal properties of mustard seeds are due to allylthiocyanate, a volatile aromatic compound which inhibits the growth of *Saccharomyces cerevisiae.* Mustard seeds promote growth of lactic acid bacteria and inhibit scum yeasts which can break down lactic acid. Essential spice oils such as thyme, sage, lemon and dill inhibit the growth of different yeasts in fermentation of olives, thereby, prolong in the effectiveness of lactic acid fermentation. Chemical preservatives such as sorbic acid inhibit fungi, yeasts and bacteria without interfering with the development of lactic flora.

16.12 PRESERVATION OF WHOLE TOMATO CONCENTRATE

Tomato is considered a necessary adjunct of almost all vegetable curries throughout the country. It adds to their taste, lends colour and supplements the nutritional quality of the vegetable preparations. Tomato crush is a distinct type of product which contains the whole of tomato inclusive of skin and seeds and thus differs from tomato puree and paste.

The tomato crush is prepared by boiling the tomatoes, blending and continuing to boil till a thick consistency. Preservatives are added to it prolong its shelf life. For every kilogram of the thick paste, 5ml of glacial acetic acid is added followed by boiling for 8-10 minutes. Then to the hot one kilogram of tomato crush, 0.4g potassium metabisulphite and 0.2 g sodium benzoate are added after dissolving in a small quantity of water. This mixture of two preservatives retains better red colour (lycopene) in tomato crush.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is meant by steeping preservation?

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2. What is fermentation and what are its advantages?

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16.13 LET US SUM UP

In this unit on chemical additives we have examined the role of food additives in the food industry. This has included the study of the classes of different food additives, their role and mode of action, nutritional additives, the permitted preservatives and their applications.

We have also studied the simple, low cost, low energy processing technologies which are needed to keep the processed and preserved products within the reach of a much wider section of the population. These methods of chemical preservation and fermentation are easy to follow, economical and cater to the indigenous need, save losses of fruits and vegetables as well as their valuable nutrients, utilize market surplus, promote horticulture and give boost to the preservation industry, benefit the consumers and provide better returns to growers.

The chemicals, which are intentionally added to our food, constitute a small but important part of the many chemicals which man is adding to his environment. These chemicals are needed to efficiently produce an abundance of high quality food. The global and the scientific view still include unintentional and generally recognized additives as safe materials. Unintentional additives may have been incorporated into the food during its production, processing, storage or marketing. Intentional food additives include chemicals, which are used for nutritional purposes, consumer acceptance, preservation of quality and processing. The changing food industry allows the homemaker of today to spend only 90 minutes per day in the kitchen compared with the 5 hours used by her mother. Her convenience foods, which save time, effort and sometimes money, contain many of the direct additives.

16.14 KEY WORDS

Food additive : A substance or a mixture of substances other than the basic food stuff, which is present in food as a result of any aspect of production, processing, storage and packaging and does not include chance contaminants.

GRAS : Additives which are Generally Recognised As Safe.

Preservative : Substances which when added to food retard, inhibit or arrest the activity of microorganisms such as fermentation, acidification and decomposition.

Steeping preservation : Preservation in a chemical solution that contains various food additives such as organic acids (glacial acetic acid, citric acid, lactic acid), chemical preservatives (potassium metabisulphite, sodium benzoate) along with salt, sugar, spices etc. in water, and checks enzymatic, oxidative and microbial spoilage in the preserved material.

Whole tomato crush : Tomato product which contains the whole of tomato inclusive of skin and seeds.

16.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Food additives help to improve the quality of food we eat. They enhance the consumer acceptability, help to maintain the nutritional quality, stability of the food, check spoilage by inactivating microorganisms, facilitate preparation of food and improve palatability e.g.: Preservatives, antioxidants, colouring agents, texture modifiers, antifoaming agents, acidulants, flavours etc.

2. Class I preservatives are natural products e.g.: salt, sugar, dextrose, spices, vinegar, honey etc which can be used at a higher concentration to preserve foods. Class II preservatives are synthetic chemicals such as benzoic acid, sulfurous acid, propionic acid, nitrites, nitrates etc. which are used in small concentrations to preserve food.

3. Your answer should include the following points.

   - Additive means any substance which is not a normal constituent of the food material and is purposeful addition which is aimed for technological, organoleptic and nutritional reasons.
   - According to the WHO, a food additive is defined as a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging. The term does not include chance contaminants.
   - Food additives have also been defined by the National Academy of Sciences as those chemicals that may be incorporated in foodstuffs, either directly or indirectly during growing, storage or processing of foods.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Steeping Preservation implies preservation in a chemical solution that contains various food additives such as organic acids (glacial acetic acid, citric acid, lactic acid), chemical preservatives (potassium metabisulphite, sodium benzoate) along with salt, sugar, spices etc. in water, and checks enzymatic, oxidative and microbial spoilage in the preserved material. It helps to preserve foods for more than a year.

2. Fermentation implies decomposition of carbohydrates and carbohydrate like substances under aerobic and anaerobic conditions. It helps to break complex material to easily digestible form and make it easily digestible. Fermented food have prolonged shelf life, require less time for cooking and increased digestibility and acceptability.

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EXPERIMENT 1 ASSESSMENT OF POST HARVEST LOSSES AT DIFFERENT LEVELS (FROM FIELD TO CONSUMERS)

Structure

1.1 INTRODUCTION

Assessment of Post Harvest losses from field to consumers is extremely important from the point of post harvest management. Saving all these losses indirectly means increase in availability of the commodity and finally helping the society. Estimating losses at different levels such as farm, wholesale and retail can accomplish the loss assessment by adopting appropriate sampling procedure at each stage. You should understand that a modest improvement in reducing wastage per unit handled at each level when multiplied by millions of unit at each stage in post harvest system could significantly increase the availability of fruits and vegetable.

Objectives

After studying and performing this experiment, you should be able to:

- determine pre-harvest loss of fruits & vegetables at field level due to insect, pest and disease incidence as well as the harvesting damage; and
- determine post-harvest loss of fruits & vegetables due to poor marketing efficiency including faulty packaging, inefficient transport, and inadequate storage facility at traders level.

1.2 EXPERIMENT

1.2.1 Principle

Pre and post harvest care of fruits and vegetables in India is by and large very poor which lead to high losses. The poor marketing efficiency including faulty packaging, inefficient transport, and inadequate storage facility is indirectly reflected in high loss. It is important to know the magnitude of post harvest losses at different stages of marketing as well as at farm. More attention to be given where losses are more and immediate corrective measures should be taken to reduce such losses.

1.2.2 Requirements

- Physical Balance/weighing scale.
- Quality assessment instruments viz. Refractometer, Pressure tester etc.
- Questioner/check list (To obtain data on losses at different level, from farmer, traders etc during survey).

1.2.3 Procedure

- Collect the loss assessment data by interviewing the farmers and traders on fresh, affected/ decayed/damaged/diseased quantity produced and handled respectively.
- Best way would be to draw a sample from the harvested produce of each commodity at farm level and a sample for each commodity at traders level taken randomly to assess the losses.
- At each stage segregate the sample into fresh/marketable and affected/unmarketable produce.

1.2.4 Observations

The sample of the fruits and vegetable collected is initially sorted into fresh (marketable) and unmarketable (decayed, diseased, damaged etc). The unmarketable ones are partly sold or processed (deformed, over/under size but free from spoilage) and partly rejected (diseased or decayed). The percentage of fresh (marketable) and affected (unmarketable) parts of the sample of fruits and vegetables at each level can be worked out easily.

1.2.5 Calculations

$$\%\ \text{loss} = \frac{\text{Q2 affected/unmarketable produce}}{\text{Q total quantity of sample}} \times 100$$

$$\%\ \text{fresh} = \frac{\text{Q1 fresh/marketable produce}}{\text{Q total quantity of sample}} \times 100$$

Q = total quantity of sample (Q1+ Q2)

Q1= fresh/marketable

Q2= affected/unmarketable

1.2.6 Result

Loss assessment is expressed = Percent (w/w)

1.3 PRECAUTIONS

- Prepare questionnaire for the interview of farmers and traders well in advance.
- Questions to be asked in a friendly manner in order to extract the maximum facts.
- Samples to be drawn at farmers and traders level with utter care so that it gives representative sample.

EXPERIMENT 2 DEMONSTRATION OF VALUE-ADDITION — BY POST HARVEST HANDLING AND PACKAGING

Structure

2.1 INTRODUCTION

Horticultural produce, in general, and fruits and vegetables, in particular, if they are properly handled i.e. sorted, graded, waxed, pre-cooled and unit packed can produce value added products. Unfortunately, in our country most of the fruit and vegetables immediately after harvest are sent to the market as a result a huge quantity of unwanted materials are also sent but if they are timely eliminated before marketing and gainfully utilized can not only add indirect value to the product but also reduce garbage in the metro cities. Ideally fruits and vegetables after harvest should be sorted, graded, waxed, pre-cooled and unit packed at packing stations situated at appropriate points in every district. This process will reduce the transportation and handling cost of inedible parts and help the consumer by providing a convenience food that can fetch higher price.

Objectives

After studying and performing this experiment, you should be able to:

- determine the importance of sorting, grading, waxing, pre-cooling and packaging, and how it can directly add value to the harvested produce; and
- determine the amount of fresh/marketable materials from the harvested lot and how to add value to the cull fruits and vegetables by making processed product.

2.2 EXPERIMENT

2.2.1 Principle

Sorting removes unwanted materials that are obviously unsuitable for sale, such as fruits and vegetables with severe mechanical injury, decay and under or over size that are unsuitable for fresh marketing. While grading groups commodity based on size, shape, colour etc. and is necessary to get suitable returns with respect to the quality attributes of the commodity. Acceptability depends on the size, attractiveness and organoleptic quality of the particular commodity. Therefore sorted and graded produce will add value. Waxing is an extra discontinuous layer applied manually or mechanically for the purpose of replacement of natural wax. This reduces water loss, gives cosmetic appearance and provides better shelf life. Prompt pre cooling reduces water loss and physiological activity, limits the growth of decay organisms, maintain quality and increase the shelf life. Ideal packaging reduces undue damage during handling and transportation, while unit packaging provides convenience and thereby increases the value of the commodity.

2.2.2 Requirements

- Sorting and grading – plastic crates and stainless steel/aluminium top tables, stools and weighing scale.
- Waxing – wax emulsion, perforated trays and electric fans.
- Precooling – ice, bucket and thermometer probe type.
- Unit packaging – stretch / cling film, small pulp/plastic tray and small baskets.

2.2.3 Procedure

Sorting and grading

- Sorting and grading may be done manually or mechanically.
- In absence of a mechanical sorter and grader an experienced person can undertake both these operations efficiently.
- After collecting the sample of the fruits and vegetable, sort out the fresh/marketable and unmarketable/decayed/diseased/damaged ones.
- After sorting out fresh/marketable fruits and vegetable, grade them according to soundness, firmness, cleanliness, size, shape, weight, colour and maturity.
- But the most prevalent practice is size grading.

Waxing

- Wax the fruits by dipping them in wax emulsion for 30-60 seconds or give a spray of wax.
- Remove excess wax by allowing them dripping.
- Dry with the help of an electric fan.

Pre-cooling

- Collect the sorted and graded fruits and dip them in a bucket containing ice water.
- This is known as hydro cooling you follow this practice in fruits but not in all horticultural commodities.
- In the case waxed fruits one should follow air-cooling.

Packaging

- Ideally after sorting, grading and waxing the fruits and vegetables are packed in CFB (Corrugated fibre board boxes).
- Unit packaging of fruits and vegetables can be done conveniently with the help of stretch/cling film.
- This film has the property that under tension it stretches and when tension is released it comes back to its original forms.
- This property helps in unit packaging for retail sale.
- Take a few fruits on a tray or basket or individually and wrap them with stretch/cling film.
- The whole operation can be carried out without heat application.

The cull fruits and vegetables free from microbial infection should be processed into value added products.

2.2.4 Observations

After rejecting the unmarketable fruits and vegetables, from the harvested lot, one can easily find out the percentage of fruits and vegetables ideal for fresh market. Sorted, graded, waxed, and unit packed fruits and vegetables can fetch higher price because of better quality (appearance), reduction in transportation and handling cost and in addition it provides convenience to the consumer.

You can easily find out the effect of waxing and unit packaging by comparing the differences in terms of quality (appearance) and weight loss with that of un-waxed unpacked ones. Conducting sensory evaluation can assess the quality.

The pulp prepared and preserved from the cull fruits can be gainfully utilized for making various processed product as when required.

2.2.5 Calculations

$$\text{Idea for fresh market \%} = \frac{\text{Weight of Marketable fresh produce}}{\text{Total quantity of harvest lot}} \times 100$$

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{weight at the end of storage}}{\text{Initial weight}} \times 100$$

Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavour/odour. Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

2.2.6 Result

Weight loss and spoilage is expressed = Percent (w/w).

Freshness = Visual observations.

Sensory evaluation = overall score.

2.3 PRECAUTIONS

- Select only freshly harvested produce, which has not undergone any segregation or selection.
- If freshly harvested produce is not available collect representative sample from the bulk arrival in wholesale market.
- Packaging should only be done with the sorted and graded fruits and vegetables.
- Avoid rough handling of the material
- Sorted fruit and vegetables unfit for fresh marketing due to under size, oversize, deformed, physically damaged but free from microbial spoilage should be kept carefully for processing into a value added product.

EXPERIMENT 3 ON FARM STORAGE — PUSA ZERO ENERGY COOL CHAMBER

Structure

3.1 INTRODUCTION

In a tropical country like India, a tremendous amount of quality deterioration of horticultural produce takes place immediately after harvest due to lack of on-farm storage facilities. Refrigerated cool storage is considered to be the best method of storing fruits and vegetables. However, this method is not only highly energy intensive but also involves huge capital investment. The present trend world over is to develop a simple low cost cooling system for storage of fruits and vegetables. In order to overcome the problem of on farm storage, low cost environment friendly Pusa zero energy cool chambers have been developed. The greatest importance of this low cost cooling technology lies in the fact that it does not require any electricity or power to operate and all the materials required to make the cool chamber are available locally, easily and cheaply. Even an unskilled person can install it at any site, as it does not require any specialized skill. Most of the raw material used in cool chamber is also re-usable. The cool chamber can reduce the temperature by 10-18^{o}C of ambient temperature and maintain high relative humidity of above 90% throughout the year that can increase the shelf life and retain the quality of fresh horticultural produce.

Objectives

After studying and performing this experiment, you should be able to:

- construct the Pusa zero energy cool chamber even in remote area and learn how to maintain the temperature and humidity in side the chamber; and
- demonstrate the performance of Pusa zero energy cool chamber in increasing the shelf life of fresh fruits and vegetables.

3.2 EXPERIMENT

3.2.1 Principle

Based on the principles of direct evaporative cooling, the Pusa zero energy cool chamber works. Considerable cooling effect can be obtained by evaporation of water and faster the evaporation, greater is the cooling. Evaporative cooling occurs when air that is not already saturated with water vapour is blown across any wet surface. Theoretically the lowest temperature that can be reached by the evaporation of water is the wet bulb temperature. The materials primarily used in constructing these chambers i.e. bricks and sand fortunately both has great capacity to absorb and/or retain water which evaporates slowly and steadily depending on the atmospheric temperature and humidity resulting in cooling.

3.2.2 Requirements

- Construction materials: bricks, sand, bamboo etc.
- Top cover: khas khas fixed in a bamboo-frame.
- Watering of the chambers: watering can or bucket and mug, water tank, drip system etc.
- Plastic crates for storage and plastic sheet for cover.
- Temperature and relative humidity: Maximum minimum and wet and dry bulb thermometer or digital thermo-hygrometer with extension cord.
- Hand sprayer (small) for spraying of insecticides/fungicides.

3.2.3 Procedure

For construction of Pusa zero energy cool chamber select an-upland having a nearby source of water supply.

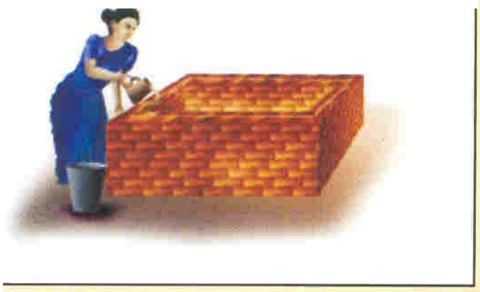
- Make floor of the chamber with the help of bricks size 165 cm × 115 cm.
- Erect the double bricks wall on the above floor to a height of 67.5 cm leaving a cavity of 7.5 cm.
- Drench the chamber with water and soak the fine riverbed sand with water. Fill the cavity between the double brick wall with this wet sand.
- Make a frame of top cover with bamboo (165 cm × 115 cm) frame and 'sirki' straw or dry grass.
- Make a thatch/tin/asbestos shed over the chamber in order to protect it from direct sun or rain or snow.
- After construction following operation instructions are to be followed. Keep the sand, bricks and top cover of the chamber wet with water.
- In order to achieve desired temperature and relative humidity, water twice daily (morning and evening). Alternatively, fix a drip system for watering with plastic pipes and micro tubes connected to an overhead water source.
- Store the fruits and vegetables in this chamber by keeping in perforated plastic crates. Cover these crates with a thin polyethylene sheet.
- The cool chamber should be reinstalled once in 3 years with new bricks utilizing the old bricks for other purposes.

DIAGRAM FOR CONSTRUCTION OF PUSA ZECC

1. Making floor of chamber

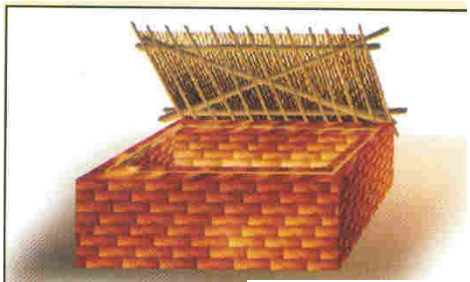
2. Erecting double wall with cavity

3. Watering the chamber



4. Filling wet sand

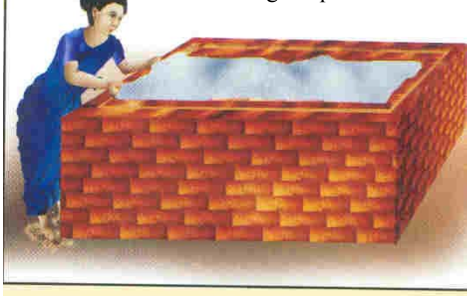
5. Making top cover



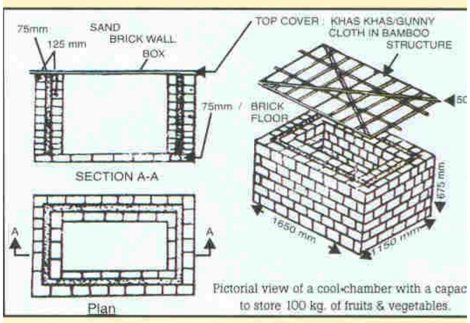
6. Cool chamber

7. Storing in plastic crates/baskets

8. Covering the plastic sheet



9. Cool Chamber under shed



3.2.4 Observations

Once the Pusa zero energy cool chambers is constructed, regular observations to be taken regarding the performance of cool chamber in terms of temperature and relative humidity as well as the shelf life increase of fruits and vegetables.

Temperature and Relative Humidity can be recorded with the help of Max. Min. Thermometer and Dry & Wet bulb Thermometer, otherwise it can be done with the help of digital thermo-hygrometer for display of temperature and relative humidity.

The shelf life increase of fruits and vegetables is recorded regularly by taking the weight, incidence of spoilage/diseases and assessing the quality (sensory evaluation).

3.2.5 Calculations

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{weight at the end of storage}}{\text{Initial weight}} \times 100$$

$$\text{Spoilage (\%)} = \frac{\text{Weight of spoilt material}}{\text{Initial weight}} \times 100$$

Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavor/odour.

Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

3.2.6 Result

Weight loss expressed as Percent (w/w).

Spoilage expressed as Percent (w/w).

Freshness expressed as Visual observations.

Sensory evaluation expressed as overall score.

3.3 PRECAUTIONS

- The site should be selected where breezes blow and should be build in an elevated place to avoid water logging.
- Only clean, unbroken bricks with good porosity must be used sand should be clean and free from organic matters, clay etc.
- The bricks and sand should be kept saturated with water. The chamber should not be exposed to sun, rain or snow.
- Only plastic crates should be used for storage and avoid bamboo baskets, wooden/fibre board / boxes, gunny bags.
- Efforts should be made to prevent water drops coming in contact with stored material.
- The chamber should be kept clean and disinfect the chamber periodically with permitted insecticide/ fungicide/ chemical, to protect from fungus, insect / pests, reptiles, etc.

EXPERIMENT 4 SOLAR DRYING OF FRUITS AND VEGETABLES

Structure

4.1 INTRODUCTION

Preservation of food by drying is perhaps the oldest method. Large quantities of fruits and vegetables are dried in the sun in different parts of the world. Sun drying or solar drying of fruits and vegetables is practiced widely in tropical and sub-tropical regions where there is plenty of sunshine and practically little or no rain during the drying season. Only small capital investment is required with this simple procedure. Advantages of dehydrated fruits and vegetables are more viz. mineral content remain unchanged, hardly affects the main calories-providing constituents of food, long shelf life if packed and stored properly, transportation, handling and storage costs are substantially reduced and finally the consumer uses all that he buys thus no waste disposal and pollution problems. However, there are some disadvantages, since sun drying depends on uncontrolled factors, production of uniform and high quality product is not expected. Some over drying and contamination by dust, dirt, and insect infestation of the finished products is usually tolerated. It is a slow process, unsuitable for producing high quality products. If the ancient sun-drying technique is improved by creating ideal system of solar drying then quality of the dried product also be improved.

Objectives

After studying and performing this experiment, you should be able to:

- demonstrate the techniques of pre-drying treatments required for fruits and vegetables to produce a quality-dried product; and
- display the Improved Solar Drier / Black Polyethylene Cover drier by actually drying some fruit or vegetable following ideal conditions of packaging and storage of solar dried fruits and vegetables.

4.2 EXPERIMENT

4.2.1 Principle

The major purpose of drying or removal of water/moisture from fruits and vegetables is to protect them against deterioration. Microbes cannot grow and multiply in absence of sufficient water in the environment. Many of the enzymatic reactions are hydrolytic in nature and require water as one of the reactants. Chemical reactions in food materials are also slowed down in absence of an adequate water. Therefore, by removing water from the fruits and vegetables, it should be possible to preserve them by checking the spoilage causing agents. This principle forms the basis for preservation of fruits and vegetables by drying. Employing blanching, sulphuring or sulphitation can improve the quality of sun-dried fruit and vegetable products. The retention of green colour and β-carotene (provitamin A) can be improved by indirect solar drying. The quality of the dried fruits and vegetables can be retained successfully if they are ideally packed in moisture proof pack and stored in cool dry place.

4.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top
- Stainless steel peeling, coring and pitting knives
- Blanching tank/aluminum vessel
- Gas burner/heating arrangement
- Cooling tank
- Sulphitation/ SS tank or aluminum pan
- Sulfuring/Sulfur box
- Perforated aluminum trays
- Solar drier/facility for sun drying
- Black polyethylene sheet
- LDP/HDP pouches, Pouch sealing machine. Tin container with airtight closure.

4.2.3 Procedure

- Select fruits and vegetables very carefully for drying.
- Wash the fruits and vegetables thoroughly to remove any dirt and other extraneous matter.
- Prepare the fruits and vegetables by peeling and cutting into suitable sizes on the day of harvest itself.
- In the case of fruits, sulphuring is done as pretreatment to maintain their colour and also to avoid spoilage by microorganisms.
- Prepared fruits are then exposed to sulpher fumes by burning sulphur in a sulpher box.
- Blanching is used as pretreatment for vegetables, this is done by rapidly boiling the vegetables in water for known time to inactivate the enzymes and partially killing the microorganism.
- Immediately after blanching the vegetables are dipped in cold water to avoid over cooking.
- The blanched vegetables are sulphited by placing them in 0.5% solution of potassium metabisulphite for requisite time.

- The fruits and vegetables are then spread on perforated tray, dried in direct sun or in shade preferably in a well - ventilated room away from direct sunlight. Provision of a ceiling fan in the room will hasten the process of drying.
- Solar drying can be improved considerably by using black polyethylene structure.
- It should be made in such a way that it could hold trays containing fruits and vegetables for drying with the provision of entry of dry air from the bottom and exit of moist air from the top of the structure.
- The samples should be turned every 4-6 hours for uniform drying.
- Dried fruits and vegetables are highly susceptible to contamination and therefore, should be packed in polyethylene (plastic) bags/pouches as soon as they are cooled after drying is over.
- In order to prevent rodent attack, the plastic bags are placed in metal containers and closing the lid firmly.

4.2.4 Observations

During sun/ solar drying, it is necessary to observe that there is plenty of sunshine and practically little or no rain during the drying season. Weigh the trays at regular interval to determine the drying the rate. The vegetables should preferably be dried to a moisture level of about 5%, i.e. till the vegetables become crisp/brittle. In case of fruits higher moisture can be retained because of the presence of sugar. Observations are to be made on the aspect viz. drying rate, and ratio, final moisture content of the material and re-hydration ratio. Finally the quality has to be determined.

4.2.5 Calculations

The dehydration ratio can be worked out by taking the initial weight of the fruit or vegetable and final weight of the dried product.

$$\text{Dehydration ratio} = \frac{\text{Initial weight of the fruit or vegetables}}{\text{Final weight of the dried product}}$$

$$\text{Rehydration ratio} = \frac{\text{Weight of the dried fruit or vegetable}}{\text{Final weight of the soaked dried product after draining water}}$$

$$\text{Moisture (\%)} = \frac{\text{Initial weight} - \text{weight after drying}}{\text{Initial weight}} \times 100$$

Organoleptic quality / Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavour/odour. Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

4.2.6 Result

Yield of dried product and moisture is expressed as Percent (w/w).

Drying and rehydration as Ratio.

4.3 PRECAUTIONS

- For the purpose of drying select fruits and vegetables in prime condition of eating and cooking.
- Recommended pre-treatments and drying process should be strictly followed.
- Care must be taken to see that the dried products are packed at the right time and do not pick up moisture
- Rodent attack on the plastic pouches must be prevented.

EXPERIMENT 5 PRIMARY AND MINIMAL PROCESSING

Structure

5.1 INTRODUCTION

In India, perishable fresh fruit and vegetables are marketed immediately after harvesting without primary processing and adequate packaging. On the other hand, in the developed countries, most of the fruits and vegetables after harvesting are transported to packing stations for primary processing. They are then trimmed, sorted, graded, unit packed and marketed. In our country, because of the absence of primary processing, a lot of inedible material is transported to the market and finally to the homes of consumers where they end up in the garbage bin. Primary processing is therefore, necessary to streamline the marketing of fresh horticultural produce to urban markets. The solid wastes originating from horticultural crops in metro cities can create drainage problems and cause water logging, as well as invite stray animals near garbage dumps. These bio wastes also deteriorate very rapidly causing unhygienic conditions and increasing atmospheric pollution and provide a breeding ground for insects, pests and rodents. Minimally processed fruits and vegetables are cleaned, peeled, cut, sliced, packaged and/or lightly processed. These foods are in great demand because of their convenience. All fruits and vegetables need not be minimally processed. It is very often not convenient for the consumer with a small family to purchase commodities like pineapple, jackfruit, watermelon, pumpkin, ashgourd, yam, etc. Therefore if it is suitably sliced, peeled and packed consumer will be more inclined to buy it. In metro cities minimally processed vegetables like primary processing can solve one of the greatest problems of garbage disposal.

All fruits and vegetables need not be minimally processed. It is very often not convenient for the consumer with a small family to purchase commodities like pineapple, jackfruit, watermelon, pumpkin, ashgourd, yam, etc. If the vegetables are available in ready to cook form a large number of workingwomen in metro cities will be greatly benefited.

Objectives

After studying and performing this experiment, you should be able to:

- demonstrate the techniques of primary processing of fruits and vegetables and show how the solid wastes originating from fruits and vegetables can be utilized in the farmers field thereby reducing cost of transport and the city garbage; and

- explain with practical demonstration of techniques of minimally processed fruits and vegetables and highlight its advantages.

5.2 EXPERIMENT

5.2.1 Principle

There is little difference in principle between primary and minimal processing. Primary processing is applicable in some fruits and vegetables, which carries lots of inedible/unmarketable part from the field to the market. Therefore, the main principle of primary processing is to eliminate the inedible parts without inflicting any damage to the main edible part. While minimally processed fruits and vegetables are cleaned, peeled, cut, sliced, packaged and/or lightly processed. One should keep in mind that while supplying minimally processed vegetable the maintenance of quality and hygiene must be of topmost priority.

5.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top.
- Stainless steel peeling, coring and pitting knives.
- Stainless steel washing tanks, constant supply of potable water.
- Electric fan / blower / drying arrangement.
- Packaging in polyethylene pouches, small plastic crates, CFB boxes.
- Pouch sealing machine.
- Shrink wrap/cling films, small cardboard tray/bamboo basket/perforated plastic container.
- Refrigerated storage/ walking coolers.
- Stainless steel pretreatment tanks.
- Laboratory facilities.

5.2.3 Procedure

Both the primary processing and minimal processing can be explained properly by giving example of a particular fruit or vegetables.

Primary processing

Cauliflower

- Procure cauliflower immediately after harvest
- Remove the inedible outer leaves and stems by cutting them with sharp knife without inflicting any damage to the edible curd
- The curds can be either wrapped in plastic film or kept as such in plastic crates for shipment in the market.
- The leaf and stem portions eliminated can be used as cattle feed or any other value added products.

Banana

- Harvest mature banana bunches carefully without causing any damage to banana fingers.
- Separate the banana hands from the bunch with help of a sharp knife.
- If facilities available wash the hands wax and dry them.
- Put the banana hands individually in plastic bag and place them in the crates for shipment.
- The banana stems left out can be used as value added product.

Minimal processing

- Select good quality fruits and vegetables for this purpose.
- Peel the fruits and vegetables and cut them into convenient pieces.
- Place them into appropriate containers or pouches for marketing.
- Some pre-treatments are recommended varies from commodity to commodity should be followed strictly.
- Transport and store the minimally processed under refrigerated condition.

5.2.4 Observations

It is advisable to maintain strict hygienic condition of the place and equipment. Strict vigil on the quality of primary and minimally processed fruits and vegetables are to be carried out. Yield of primary and minimally processed fruits and vegetable is to be recorded.

Shelf life or marketable life can be observed by determining the quality both in terms of microbial and organoleptic quality.

5.2.5 Calculations

The yield of the finished product and weight loss during storage should be determined.

$$\text{Primary processed produce}\,\% = \frac{\text{Weight of primary processed produce}}{\text{Weight of the original fresh produce}} \times 100$$

$$\text{Minimally processed produce}\,\% = \frac{\text{Weight of minimally processed produce}}{\text{Weight of the original fresh produce}} \times 100$$

$$\text{Waste}\,\% = \frac{\text{Weight of waste}}{\text{Weight of the original fresh produce}} \times 100$$

Sensory evaluation = Experienced assessors randomly selected should evaluate overall acceptability, colour, texture and flavour/odour. Attributers are to score on five point hedonic scale of excellent, 1; good 2; fair 3; poor, 4; and very poor, 5.

5.2.6 Result

Yield and wastage expressed as Percent (w/w).

Quality assessment is reported on Hedonic scale.

5.3 PRECAUTIONS

- Handle only freshly harvested horticultural produce for this purpose.
- Care must be taken to see that surface moisture from the finally prepared material before packaging should be removed.
- Once the primary/minimally processed fruits and vegetables are prepared and packed it should straight away go to refrigerated store.
- Keep rejects such as peel, seeds/stones or any other vegetable parts carefully for processing into a value added products and not thrown as garbage.

EXPERIMENT 6 EXTRACTION AND PRESERVATION OF PULPS AND JUICES

Structure

6.1 INTRODUCTION

The demand of fresh juices and pulp are increasing very rapidly. They are rich in essential minerals, vitamins and other nutritive factors. Freshly extracted fruit juices and pulp are the most palatable. It is desirable that juices and pulp should retain quality characters satisfactorily to the maximum extent while extraction. One should keep in mind that extraction of fruit juices and pulp are of utmost importance. There is no guidelines or specification that particular equipment is dedicated to extraction of juice or pulp of a particular fruit. It entirely depends on the equipment that gives the best juice or pulp of high quality. Generally, crushing and pressing extract juice from fresh fruits. In one case it is done continuously in one operation where as in the other the fruits are either crushed or cut into small pieces/halves and subsequently juice is pressed out. There are various types of equipment used in extraction of fruit juices and pulp.

Freshly extracted juices and pulps are highly attractive in colour and excellent in flavor, but deteriorate very rapidly if they are not preserved immediately, various factors influence and/or accelerate the loss of quality both internally and externally. The internal factors viz. water content, chemical composition; enzyme system etc. and the external influences such as temperature, hygiene or presence of contaminants play a significant role in retaining the quality of juices and pulp. There are various ways for the preparation of fruit juices and pulps, but preservation of pulp and juices by chemical preservatives, heat processing and freezing are very popular.

Objectives

After studying and performing this experiment, you should be able to:

- learn different methods and equipment to be used for extraction of juices and pulp that depends upon the structure of fruit, location and character of the tissues in which the juice is located;
- learn how to avoid destruction of vitamin C and undesirable oxidative changes in colour and flavour that occur during extraction and subsequent processing;

- conduct experiment/practical on how pulp and juices can be preserved by heat processing; and
- demonstrate preservation of pulp and juices by chemical preservatives.

6.2 EXPERIMENT

6.2.1 Principle

The method of extraction of pulp and juices depends upon the structure of fruit, location and character of the tissues in which the juice is located. In fruits like aonla, apple, grapes etc the juice is located throughout the fruit and is readily recovered by crushing and pressing. While in case fruits like apricot, peaches, plum, mango, tomato etc. the raw or cooked fruits are passed through a pulper or similar machine. In case of citrus fruits the juice is embedded in a sac and it requires entirely different machine such as halving and burring machine halving and burring machine. One must remember that undue aeration must be avoided during the extraction of juices/pulp from fruits that have not been heated to destroy enzymes, since destruction of vitamin C and undesirable oxidative changes in colour and flavour takes place. It is necessary to remember that the metal equipment should not contain traces of iron and /or copper that deteriorate the quality.

Fruit juices and pulp are generally preserved by application of heat, addition of chemicals and by freezing. Both the microbial and enzymatic spoilage can be well checked by application of heat. Preservation of pulps and juices by application of heat is known as pasteurization, in this process the pulps and juices are heated below 100° C but above 88° C to kill spore-forming bacteria, mould and inactivate enzymes. Acid fruit juices and pulp require lower temperature and less time for pasteurization than the less acid ones. Chemical preservatives are substances capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of fruit juices and pulps. The permitted preservatives used in this country are sodium benzoate and potassium metabisulphite where the active agents are benzoic acid and sulphur dioxide respectively. Generally beverages like squashes, cordial etc. are preserved by chemicals as well as bulk preservation of pulps and juices.

6.2.2 Requirements

Requirements for extraction and preservation of pulps and juices are as follows:

Extraction

- Pulpers
- Screw type juice extractor
- Citrus juice extractor/ Rosing machine
- Citrus halving machines
- Fruit mill/fruit grater
- Basket press/hydraulic press/rack and cloth press,
- Crown corking/pp cap sealing machine
- Gas burner/heating arrangement
- Double seamer / crown corker

- Processing & cooling tank
- Stain less steel storage tanks
- Sterilization equipment
- Thermometer
- Aluminum pan
- Wooden laddle
- Mixing tank

Preservation

- Sodium benzoate
- Potassium metabisulfite (KMS)
- Citric acid
- Bottle filling machines
- Beer bottles, Jerry cans, Glass containers and closures

6.2.3 Procedure

Extraction

In general you can extract juices/pulp from fresh fruits and vegetables by crushing and pressing, but the method of extraction and equipment used varies. It would be more clear once it is explained with examples as follows:

Mango, tomato, papaya etc.

- These are all pulpy fruits therefore a pulper can extract the juice/pulp easily.
- Peel and cut the fruits in general before placing in the pulper.
- These are then crushed and pressed by the paddles against the cylindrical sieve.
- The juice/pulp flows out through the sieve into jacket and collect the juice/pulp by placing in a container below the pulper.
- The coarse residue, stone etc, passes out at the lower end of the sieve.

Citrus fruits

- Cut the citrus fruits in to two halves by revolving or stationery knife.
- Hold or press the cut half against the revolving burr or rose of extracting machine.
- Collect the reamed juice in a container placed below.

Apple, aonla, grape, pineapple, jamun, carrot etc.

- In order to extract the juice from the above-mentioned fruits and vegetables you have to grate or crush them in a grater or crusher.
- Then place the grated or crushed mass in a filter cloth tie it properly but loosely.

- Carefully put the filter cloth containing grated or crushed mass inside the basket.
- Put the load/wooden disc on the filter cloth containing grated or crushed mass and press the juice out by hand operated or hydraulic type press.

All the three types extraction methods are explained above however it is necessary to mention that the Screw type juice extractors can be used universally for extracting juices/pulp from all types of fruit pieces including citrus segments.

Preservation

The following two methods of preservation are to be conducted.

Heat processing

- Preservation of juices and pulps by heat processing are most popular and desirable method.
- Heat the juice or pulp to about 100o C for sufficient time to kill the microorganisms causing spoilage.
- Fill the almost boiling hot juice in preheated glass bottles without giving any head space and crown cork immediately.
- Keep the bottles in a horizontal position and cool them in air.
- Preserve the fruit and vegetable pulp by heat processing in open top can or in wide mouth bottles having closures, which can be sealed hermetically.

Chemical preservatives

- You know two permitted preservatives viz. i) sodium benzoate and ii) Potassium metabisulphite (KMS) used in preservation of fruit and vegetable juices and pulps.
- Benzoic acid is an effective agent but it is sparingly soluble in water however, its sodium salt is water-soluble therefore sodium benzoate is used.
- Addition of 0.06 to 0.1 percent sodium benzoate is sufficient in juice having a pH of 3.5 to 4.0.
- Potassium metabisulphite is soluble in water and used as a stable source of sulphur dioxide, which is an effective agent.
- Addition of 0.15–0.2 percent potassium metabisulphite is sufficient in juice/pulp having a pH of 3.5 to 4.0.
- Weigh exact amount of preservative and dissolve in small quantity of freshly boiled and cooled water before adding to heated and cooled pulp/juice.
- Fill in the container (glass jar, jerry can etc) and close it securely so that sulphur dioxide does not escape.

6.2.4 Observations

The main observations to be taken are selection of fruits, % of juice, % of pomace/rag, % of peels, % of stone, % of unknown loss, % of acidity and degree Brix or % of total soluble solids (TSS).

6.2.5 Calculations

$$\text{Juice (\%)} = \frac{\text{Weight of juice extracted}}{\text{Initial weight of the fruit}} \times 100$$

$$\text{Pomace/rag (\%)} = \frac{\text{Weight of residue after extraction}}{\text{Initial weight of the fruit}} \times 100$$

$$\text{Stone (\%)} = \frac{\text{Weight of stone removed}}{\text{Initial weight of the fruit}} \times 100$$

Calculation for acidity and degree Brix or total soluble solids (TSS), you should consult the practical manual viz BPVI-003 and BPVI-007.

6.2.6 Result

- Yield of juice is reported as Percentage
- Yield of pomace is reported as Percentage
- Yield of peel is reported as Percentage
- Yield of seed is reported as Percentage
- Acidity is reported as Percentage
- Total soluble solids (TSS) = % or ^{o}Brix

6.3 PRECAUTIONS

- Avoid overripe and microbiologically spoiled fruits for making juice and pulp.
- Wash the extractors and other equipment with hot water to reduce the chance of infection.
- Preserve the juice and pulp immediately after extraction in order to avoid quality deterioration and incidence soilage.
- Dry the pomace immediately in order to avoid spoilage and use it for the production of value added products.

EXPERIMENT 7 PREPARATION OF WHOLE TOMATO CONCENTRATE

Structure

7.1 INTRODUCTION

Tomato is one of the few nutritious vegetables, which has a great demand both in the fresh and processed form. During the season of abundance when there is a glut in the market and tomatoes are sold at through away prices and the growers do not get the remunerative price. It is an item of daily use and also an important ingredient in our culinary system. Unlike other ingredients such as onion, garlic, ginger etc. which are peeled/scaled before using, tomato is added whole without eliminating seeds or peel portion while cooking either in vegetarian or non-vegetarian food. Therefore, there is a great scope of preserving the whole tomato in the concentrated form along with its seeds and peel.

Objectives

After studying and performing this experiment, you should be able to:

- determine the importance of preserved tomatoes in the form of whole tomato concentrate to be used in off- season or when they are very costly in the market; and
- determine the importance of low cost processing of tomato in value addition and retention of quality attributes particularly the colour i.e. Lycopene known for its anti-oxidant property and as precursor of vitamin A.

7.2 EXPERIMENT

7.2.1 Principle

Whole tomato including peel and seeds are crushed, concentrated and preserved by combination of heat and chemical preservatives. This can be used for cooking purpose when prices are more for fresh tomato. It is a complete substitute for fresh tomatoes. By this way of low cost preservation, a huge quantity of post harvest loss of tomato can be prevented.

7.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top.
- Stainless steel knives.
- Gas burner/heating arrangement.
- Aluminum pan / stainless steel pan.
- Wooden ladle.
- Wide mouth glass or plastic bottles with closures.
- Chemicals – Acetic acid, potassium meta bisulphate (KMS) and sodium benzoate.

7.2.3 Procedure

- Select fully ripe and red tomatoes, wash them and cut into pieces after removing the green portions.
- Boil them in a stainless steel or aluminium vessel while crushing constantly with the help of a wooden ladle to get a homogenous mass including seed and peel.
- The whole tomato pulp should be concentrated to approximately one third (3 kg of fresh tomato will yield 1Kg of tomato concentrate) of its original weight when it forms a thick paste.
- Towards the end, boil the tomato concentrate for a couple of minutes by adding 0.5% glacial acetic acid.
- Cool the tomato concentrate to room temperature and add a mixture of 200ppm each of sulpher dioxide and sodium benzoate i.e. 0.4 g KMS and 0.2 g sodium benzoate per kg of concentrate after dissolving them in a small quantity of water.
- The mixture of two preservatives help in retention of red colour apart from helping in preservation of pulp.
- Fill the whole tomato concentrate in a clean dry glass/bottle and close it properly.
- Store the bottles in cool dry place and use as and when required.

7.2.4 Observations

Careful observation to be made that the green portions are totally eliminated(trimmed) tomatoes otherwise it will hamper the colour of the end product.

To avoid charring the product should be constantly stirred. The weight of the final product should be I/3 rd of the original weight.

7.2.5 Calculations

$$\text{Trimming (\%)} = \frac{\text{Weight of trimming}}{\text{Initial weight of the fruit}} \times 100$$

$$\text{Tomato concentrate (\%)} = \frac{\text{Weight of concentrate}}{\text{Initial weight of tomato}} \times 100$$

7.2.6 Result

Waste (trimmings) = %

Tomato concentrate = %

7.3 PRECAUTIONS

- Select fully ripe red tomatoes for making tomato concentrate reject the infected ones.
- Avoid over-boiling after addition of acetic acid.
- Add chemical preservatives towards end when the material is cooled to room temperature.
- Pack immediately in glass bottles or plastic pouches after addition of preservatives.

EXPERIMENT 8 UTILIZATION OF WASTE GENERATED DURING FRESH HANDLING AND PROCESSING

Structure

8.1 INTRODUCTION

One of the reasons for the food processing industries based on horticultural produce not being economically viable in our country is non-utilization of the valuable waste accumulated during handling and processing. The huge quantity of fruit and vegetable waste generated in the packhouse and fruit processing units can also be gainfully utilized for making value added products, thereby reducing the price of processed products. By doing so the processed food products of daily use of the common man will be well within their budget and food processing will become a more popular industry. In addition by utilizing the waste at the right time the problem of disposal of solid waste from the food factory can be solved to a great extent.

Objectives

After studying and performing this experiment, you should be able to:

- determine the extent of waste generated in a packing station and processing factory using fruits and vegetables; and
- explain the technique of utilization of fruits and vegetable waste material into a value added product.

8.2 EXPERIMENT

8.2.1 Principle

The waste generated both in fruit and vegetable packhouse and processing units in terms of cull fruits, peel, stone, cores, pits, seeds, trimmings, stems, pods are highly perishable. All these waste materials should be processed immediately into durable products, utilizing various techniques of preservation such as heat application, dehydration, addition of chemicals etc. otherwise they will convert into garbage. Various types of by products can be produced from the waste including both as feed material for the animal and food for human. The most common by products are pectin, citric acid, oils, vinegar, and alcohol. A large number of other materials like colour, essential oil, and nutrients can also be produced apart from processed food items like juices, jams, pickle, candies etc.

8.2.2 Requirements

- Preparation table having stainless steel sheet or aluminum top.
- Stainless steel peeling, coring and pitting knives.
- Blanching tank/aluminum vessel.
- Gas burner/heating arrangement.
- Solar drier/facility for sun drying.
- Pulpers.
- Fruit mill/fruit grater.
- Basket press/hydraulic press.
- Crown corking/pp cap sealing machine.
- Mixing tank, Beer bottles, Jerry cans for storage.

8.2.3 Procedure

As already mentioned waste generated both in fruit and vegetable pack house and processing units can be utilized for production of various types of value added products including human food and animal feed. It is not possible to describe the procedure of all these items. Therefore we have selected three items of waste, which can be gainfully utilized.

Fruit pulp from culled fruits – Fruits that are rejected both by the packing station and processing factories can be gainfully converted into pulp

- Collect the fruits (apple) and wash them thoroughly after rejecting the spoilt ones.
- Cut the apples into four to six pieces depending on the size. Remove the core portion containing seed.
- Separate the seeds and sundry them which can be sold to the nurseries
- The fruit pieces are then cooked/ boiled in requisite amount of water with constant stirring to soften them
- Pass the hot mass through a pulper or stainless sieve and collect the apple pulp.
- Adjust the acidity of the apple pulp to 0.5% with citric acid and preserve the apple pulp in a jerry can by addition of 2g of KMS (preservatives) per kg of pulp.
- The apple pulp can be used as such and you can be prepare various types of products viz. fruit slab, nectar/fruit drink, fruit toffee etc as and when required.

Cauliflower waste in packing station

Cauliflower produces about 60% leafy part and 40% edible curd. Utilize the leafy part as a value-added product both for human food and feed for cattle.

- Cauliflower produces about 60% leafy part and 40% edible curd. Utilize the leafy part as a value-added product both for human food and feed for cattle.
- Remove the thick midrib (stem) from the leafy portion and keep them separately.
- Cut both the leafy portion and the stem into small pieces and wash them thoroughly in running water.
- Blanch them separately in boiling water for 2 minutes before drying.
- Dry them separately preferably under polyethylene cover till they are crisp dry.
- Pack them in polyethylene bags and them securely in a tin container.
- Finally convert the dried leaves into cauliflower leaf powder, this is a rich source of β-carotene (pro-vitamin A) and is a potential source of fortification that could solve the acute problem of vitamin-A deficiency.
- Similarly stems cut into pieces blanched and dried could be used as animal feed in time of shortage or fodder crisis.

Candied citrus peel in a juice factory

- Collect the citrus peels after extraction of juice then remove the seeds and rags from inside the cup.
- Place the peel in 2.0 % common salt solution. Increase the strength of the solution by 2% every 24 hours until the strength reaches 8.0%. This takes about 4 days.
- On the fifth day wash the peels thoroughly and place them in freshly prepared 8.0% common salt solution. Containing about 0.2% potassium metabisuphite and 1.0 calcium chloride and store. Calcium chloride helps in keeping the peels firm.
- As and when required they are washed thoroughly in running cold potable water and then boil in order to soften them.
- After this put the peels in a vessel and cover them with cold syrup of 30° Brix and leave them for 48 hours.
- On the third day the brix will come down much below 30° it is then raised by 10 degrees, and the peels are boiled with syrup for about 5 minutes. The process is repeated until the brix is reaches 60 degrees.
- At this stage citric acid is added @ 1 g per Kg of peel. The strength of the syrup is raised to 75 degrees brix, 5 degree every day.
- The peels are then left in the syrup for 2-3 weeks. Finally they are dried on a stainless steel wire tray at room temperature till they are no longer sticky.

8.2.4 Observations

Note the amount of waste generated from a particular commodity during handling in the packing station and also while processing. Keep a record of the different types of waste and their quantity. You can add value to these waste by processing into some useful products, this will have an economic gain on the final product. This way the impact of value addition on the pricing of the original processed product can easily determined.

8.2.5 Calculations

Find out the percentage of total waste and also the percentage of different types of (leaf, stem, peel, seed/stone, core etc) waste generated from a particular commodity.

$$\text{Waste (\%)} = \frac{\text{Weight of the waste}}{\text{Weight of the commodity}} \times 100$$

Determination of economic gain, this can be done by actually calculating in terms of rupees as follows:

Price/value of the original processed product with out waste utilization = X

Price/value obtained from the waste material utilized by processing = Y

Price/value reduction of the original product X - Y = Z

Economic gain = X - Z

8.2.6 Result

Amount of waste is reported as %.

Economic gain is reported in rupees (or can also be expressed as %).

8.3 PRECAUTIONS

- Segregate the waste material like leafy portion, inedible/unmarketable parts in a packing station and seed, stone, peel and pomace in a processing industry.
- In order to avoid decomposition and stabilize the waste, dry the high moisture materials like pomace, peel etc for future use.
- Do not throw waste as it create environment pollution.

UNIT 1 AN OVERVIEW OF FOOD CHEMISTRY

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- explain what is food chemistry;
- state the historical developments in food chemistry; and
- discuss the different roles played by food chemistry.

1.1 INTRODUCTION

All of us need food for our survival and well being. We derive our food from the plant kingdom (like cereals, pulses, oilseeds, fruits, vegetables, root crops, etc.) and animal kingdom (like meat, fish, poultry, cow and buffalo, etc.). Do we know what are the constituents (nutrients) of the foods we eat? Do all foods contain the same constituents and in the same proportions or do they differ? Food chemistry has answers for all these. Today we have a fairly good knowledge of nutrient composition of all the common food materials and products so that we are able to plan a nutritionally balanced diet.

You have learnt the importance and methods of food preservation. Though we eat some foods in the raw form like fruits and vegetables, many others are stored for various length of time and consumed after cooking or converting them to some other forms as processed products like different types of wheat breads; various rice preparations, milk and meat products like cheese, yoghurt, sausages; fruit products like juices, jams, preserves; or dried and dehydrated products like mushroom powder. What changes take place in them after the food raw materials are harvested, processed and stored? Food chemistry deals with these.

Now we see numerous new ready to eat products on the grocer's shelf. They were not there 20 years ago. Steadily the numbers are increasing. How nutritious are these foods? We have become very familiar with the term 'food adulteration' but how to know whether a particular food is adulterated and if so with what it is adulterated? Yes, a food analyst can find it out.

A general overview of these aspects is given in this unit. You will be learning more details of them in the subsequent units.

1.2 WHAT IS FOOD CHEMISTRY?

Food Science deals with the physical, chemical and biological properties of foods as they relate to stability, quality, processing, safety, nutritive value, wholesomeness, convenience and cost. Food Science is an inter-disciplinary subject involving primarily bacteriology, chemistry, biology and engineering. Food chemistry, a major aspect of food science deals with the composition and properties of food and chemical changes it undergoes during handling, processing and storage. Food Chemistry is intimately related to chemistry and biological sciences like biochemistry, botany, zoology and molecular biology. The primary interests of biological scientists include reproduction, growth and physiological and biochemical (morphological) changes that biological substances undergo under environmental conditions that are compatible with life. On the contrary, food chemists are concerned primarily with biological substances that are dead or dying (post harvest physiology of plants and post-mortem physiology of muscle) and changes they undergo when exposed to very wide range of environmental conditions. That is why a food chemist is concerned with conditions suitable for sustaining the residual life processes (post harvest physiology) for example fresh fruits and vegetables during their marketing.

Both in home scale food preparation and commercial food processing, food raw material are converted into convenient forms by pounding or milling of food grains, pulses, etc., oil extraction, extraction of fruit juices, etc. Food chemists are concerned with the chemical properties of these disrupted food tissues. In other words, food chemists have much in common with biological scientists, yet they also have interests that are distinctly different and are of utmost importance to human kinds.

1.3 HISTORY OF FOOD CHEMISTRY

The origin of food chemistry is as old as human civilization and shrouded in obscurity. Until the 20th Century food chemistry did not have a clear identity and its early developments were associated with agricultural chemistry. During the period 1780-1850 many famous scientists made important discoveries, which laid the foundation of food chemistry.

Carl Wilhelm Scheele (1742-1786) is considered as one of the greatest chemist of all time who has done pioneering work in food chemistry. He isolated and studied the properties of lactose from milk, malic acid from apples and citric acid from lemon juice. He also tested a number of fruits for the presence of citric, malic and tartaric acids as well as various new chemical compounds. Antoine Laurent Lavoisier (1743-1794) also investigated the organic acid content a large number of fruits. He was perhaps the first to show that the process of fermentation could be expressed as a balanced equation. Theodore de Saussure (1767-1845) studied the CO_2 and O_2 exchange during plant respiration and determined the mineral contents of plants by ashing. Joseph Louis Gay-Lussac (1778-1850) and Louis-Jacques Thenard (1777-1857) devised the first method to determine the percentages of carbon, hydrogen and nitrogen in vegetables. Sir Humphrey Davy (1778-1829) who isolated the elements K, Na, Ba, Sr, Ca and Mg wrote books on agricultural chemistry. In his book elements of Agriculture Chemistry (1813) he stated "the most essential vegetable substances consist of hydrogen, carbon and oxygen in different proportion, generally alone, but in some few cases combined with azote (nitrogen).

Jons Jacob Berzelius (1779-1848) determined the elemental composition of about 2000 compounds there by verifying the law of definite proportions.Justus von Liebig (1803-1873) classified foods as either nitrogenous (vegetable fibrin, albumin, casein, and animal flesh and blood) or nonnitrogenous (fats, carbohydrates, and alcoholic beverages). He is also credited for perfecting methods for the quantitative analysis of organic substances by combustion. His book "Researches on the Chemistry of Food" is considered by many as the first book on food chemistry.

By the first half of the twentieth century, most of the essential dietary substances, namely carbohydrates, proteins, lipids, vitamins, minerals etc. were discovered and characterised.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is food chemistry?

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2. Name three scientists who have done pioneering work in the development of food chemistry.

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1.4 FUNCTIONS OF FOOD CHEMISTRY

Food chemistry, along with the other discipline of food science and nutrition play a vital role in ensuring nutritious and safe food to the human being. It is needless to state that to accomplish these roles, a thorough knowledge of the detailed chemical (nutritional) composition of foods is of prime importance.

1.4.1 Chemical Composition of Foods

As already mentioned, food chemistry has enabled us to know the nutrient composition of most of the common foods. This knowledge on their nutritional role and importance also accumulated. Nutrition studies showed that the human system require certain nutrients like carbohydrates, proteins and fats in large quantities and some others like vitamins and minerals in much smaller quantities. Therefore, the former group of nutrients were termed "major nutrients" and the latter 'minor nutrients'. Depending on the composition of foods, they were classified as 'carbohydrate rich (starchy) foods (e.g. Cereals, root crops), protein rich foods (e.g. meat, poultry and marine foods, legumes), fatty foods (oil seeds, fatty meat and fish) etc, Fruits and vegetables, in general are good sources of the minor nutrients viz. vitamins and minerals which have protective roles against certain deficiency diseases. Therefore, fruits and vegetables were classified as protective foods.

Knowledge on food composition and nutrition has also enabled planning and designing balanced foods suitable for different age groups, sex, convalescing, etc. Balanced food is a food formulation, which will provide all the nutrients in required quantities. Wherever, a food formulation is still deficient in certain nutrients, this knowledge enabled fortification to supplement them.

Today's nutrition literate consumers are demanding information on the nutrient content of the foods they consume. This has resulted in nutrition labelling of food products, which has become mandatory in some countries. Nutrition label provides information on the nutrient content of a particular food product and also what percentage of the Recommended Dietary Allowance of the nutrient is present in one normal serving of the product. The serving size is expressed in millilitres or grams. It is needless to state that nutrition labelling requires precise chemical analysis of the products.

In addition to the major and minor nutrients mentioned already, a number of bioactive compounds have been isolated from foods especially from fruits, vegetables and herbs. They are collectively termed 'Nutraceuticals' or 'Phytonutrients'. Some of them include: carotenoids, flavonoids, sulphides and thiols and phenolic cyclic compounds. Several of them have been shown to have antioxidative protection of the human body, suppression of cancer growth, improvement of vascular health, retardation of osteoporosis and control of cataracts. These developments have revived the old concept of 'Food as Medicine'.

The knowledge of the chemistry of food constituents has also enabled in modification of foods and food constituents. Production of fermented foods is an example of food modification. A large number of traditional fermented foods have been produced in different countries. Improvements in their processing steps and ensuring consistent quality have been possible due to the knowledge in the chemical (biochemical) reactions. You will be learning more on this in subsequent units. Production of glucose syrup and high fructose syrup from starch, protein hydrolysates from proteins are examples of modification of food constituents.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain how the knowledge of food composition helps in formulating a balanced food.

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2. What is a balanced diet?

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3. Explain nutrition labelling.

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4. What is meant by nutraceuticals?

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1.4.2 Quality Changes in Foods

Quality of a food is a complex combination of several sensory and hidden (intrinsic) attributes. You are familiar with some of the sensory qualities like colour and appearance, firmness, mouth feel, flavour, taste etc. Alterations in these qualities of a food material, like for example, fruits results in value reduction and even rejection by the buyer. All these sensory quality changes are caused by chemical (or biochemical) reactions. For example, loss of the green colour of spinach on storage or cooking is due to degradation of chlorophyll. Similarly, browning of cut apples is initiated due to enzymatic oxidation of phenolic substances. Softening of fruits for example is due to the breakdown of pectins or toughening of meat is due to post mortem chemical changes resulting in pH reduction and tissue hardening. Flavour changes are also due to chemical reactions. For example, flavour change in fatty foods called rancidity is due to oxidation of unsaturated fatty acids. You will be learning more on these in subsequent units. The important point to be understood is that once you know the chemical cause of quality deterioration, it is possible to devise methods to control it.

The hidden quality factors of food are the nutrients content, and absence of adulterants and toxicants. Hidden quality cannot be perceived by sensory means. They have to be assessed by chemical means only. Among the hidden quality characteristics, nutritional quality changes are more important in storage and processing of foods. Among the nutrients, some of the vitamins are sensitive to processing conditions. For example, vitamin C (ascorbic acid) is very heat labile. Knowledge on the chemical kinetics of the reactions has enabled development of High Temperature Short Time processing technique and also non-thermal methods of processing. Breakdown of thiamine (vitamin B1) is well known. Therefore, sulphites are avoided for preservation of foods rich in thiamine. Nutritional evaluation of processed foods has been the subject of intense studies in recent times.

The quality changes in foods during processing and storage are due to two major factors namely product factors and environmental factors. Product factors include the chemical composition of a particular food, its pH, and available water content. Environmental factors of importance are temperature and time, light, access to microbial and insect attack and gas composition of the storage atmosphere. Altering the composition of food products to control quality changes is not easily possible except removal of water (drying) even though in a few cases it has been done. For example, to prevent browning of egg powder, glucose is removed from egg by enzymatically oxidising it.

Temperature effect on quality is to a great extent controlled by storage at low temperatures. One of the major functions of packaging is to prevent or reduce the effect of light on food quality. The effect of gas atmosphere on quality is equally important. When a food product is exposed to the atmosphere (containing about 79% N2 and 21% O2) several oxidative reactions take place. Examples are oxidation of fatty acids, oxidation of ascorbic acid, oxidative changes in flavour and browning reactions. In order to prevent the effect of oxygen in canned foods, the cans are exhausted (steam heating of cans filled with the product before sealing) to expel air, fruit juices are deaerated, antoxidants are added to fatty foods etc. You will be learning these techniques in other units. Another method is to alter the gas atmosphere, especially to eliminate or reduce oxygen content in the gas atmosphere inside a package. You must have seen pillow packs (bloating pouches) of potato chips. They are filled with nitrogen to prevent browning and also to avoid physical damage to the chips. In the case of fresh fruits and vegetables, complete exclusion of oxygen is harmful. Knowledge of the biochemistry of plant respiration shows that reducing the oxygen concentration and increasing the carbon dioxide concentration can extend the storage life of these commodities. This has led to the development of Modified Atmosphere Packaging (MAP) and Controlled Atmosphere (CA) Storage of fresh fruits and vegetables. In MAP, mostly the gas composition is modified by the respiring commodities while in CA storage, the gas composition is modified physically by introducing or removing the respective gases.

Food adulterants and toxicants in foods have to be monitored to ensure food safety. This is a growing challenge to the food chemist.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the chemical basis of two sensory quality changes.

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2. List the factors responsible for food quality changes.

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3. Explain how the effect of oxygen on quality change can be overcome.

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1.4.3 Safety Evaluation of Foods

Most scientific developments have both benefits and harmful effects. Food chemistry is no exception. The new knowledge gave ample opportunity to unscrupulous purveyors for food adulteration. Practically all foods are liable for adulteration. A few examples of food adulterants are given below.

Food products	Common adulterants
Milk	Cane sugar, starch, water
Spices and condiments	Sand, colouring matter, paddy husk, lead chromate, saw dust, argemone seed
Oils and fat	Mineral oil, argemone oil, tri-ortho-cresyl phosphate (TOCP), animal fat (tallow) in vegetable fat
Cereals and cereal products	Kesari dhal, colouring matter, talc, inorganic pigments
Beverages	Artificial sweeteners, unpermitted colouring matter, excessive preservatives
Coffee and tea	Cashew nut endocarp, date seed, tamarind seed/ powder, saw dust, added colour
Ice cream	Artificial sweeteners, unpermitted colours like metanil yellow
Synthetic vinegar	Mineral acids
Alcoholic drinks	Methanol, chloral hydrate

In addition to the intentional addition of harmful substance to the food (Adulteration), food contaminants coming into foods like agricultural chemicals (pesticide residues), heavy metals, etc. also need to be monitored.

As a consequence of this public health hazard, a new branch of food chemistry called analytical food chemistry developed essentially to detect adulteration and contaminants. Along side, new legislations to make adulteration unlawful also emerged which greatly expanded efforts by chemists to learn about the native properties of foods, the chemicals commonly used as adulterants and the means of detecting them. You will be learning more on these in subsequent units.

1.4.4 Waste Management

Food processing industries produce huge quantities of wastes – solid and liquid. The liquid wastes (effluents) are loaded with high concentration of sugars and other organic substances. They are quite often discharged into nearby streams. Environmentalists cry foul for justifiable reasons. The Environment Protection Act (EPA) has stipulated various parameters for safe discharge of effluents. This means that the effluent has to be treated suitably to degrade the constituents of the effluents to the safe limits. Therefore, knowledge of the chemical composition of the effluent is vital for designing the effluent treatment protocols.

About 10 to 50 per cent solid wastes are generated while processing food raw materials. They can be in the form of fruit and vegetable peel and pomace, rice husk and bran, milling wastes of other grains and legumes, slaughterhouse wastes and fish processing wastes. The easiest way to dispose them off is to dump them in the nearest land, compost or use them as fuel. A clear knowledge on the chemical composition of the wastes has enabled isolation of by products from them, some of them more valuable than the main product. For example, more than twenty by products are recovered from the peel and pomace of citrus fruits, which brings in more returns to the industry than the citrus juice concentrate, which is the main product. Some of the by products produced are pectin, peel oil, seed meal and oil, candied juice sacks etc. You will be learning more about by product utilization in another unit.

Microbial (also biochemical) conversion of the organic compounds in the wastes to biogas (mostly methane) is another possibility to utilise the food processing wastes. Biogas can be used as fuel.

1.4.5 Societal Roles

As the time progressed, food chemists had to assume greater responsibilities, the most important being involvement in social issues. As already mentioned the developments in food chemistry have created the monster called 'Food Adulteration'. It is the responsibility of the food chemist to contain it. The food chemistry knowledge has also opened up the possibility of using numerous chemicals called food additives to modify or improve the functional properties of foods. Some of them include: antioxidants, emulsifying, stabilizing and anticking agents, and colouring and flavouring agents. Many of the new food products will not have their functional properties without the addition of some of these additives. Their number is continuously increasing. There is considerable fear, often out of ignorance on their use. Food chemists can play the role of educating and advising the public on their usage. Today food chemists are playing a very complimentary role along with the physiologists, microbiologists, nutritionists, food scientists and technologists in providing safe foods to people in the form and place where they wish to have them.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List a few examples of food adulteration.

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2. Explain with two examples how fruit and vegetable processing wastes can be utilised profitably.

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3. Is there any societal role for a food chemist? If so what is the role?

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1.5 LET US SUM UP

Food chemistry plays a number of important functions in food and nutrition. Some of them include:

- Understanding the chemical nature of food constituents has enabled planning of food formulations suitable for different categories of people.
- Knowledge on the chemical reactions these compounds undergo has helped to control quality changes by developing suitable methods and techniques.
- Food chemistry knowledge assists in food modifications like food fermentations, modified products etc.
- Detects and identifies food adulterants there by ensure food safety.
- Enables proper and profitable management of food processing wastes.
- Advises on judicious use of food additives.

1.6 KEY WORDS

Food chemistry	:	Study of food constituents, their properties and changes during handling, processing and storage of foods.
Major nutrients	:	Carbohydrates, proteins and lipids.
Minor nutrients	:	Vitamins and minerals.
Nutrition labelling	:	Label of a packaged food product showing the content of its different nutrients per serving.

Nutraceuticals	:	Bioactive compounds like carotenoids, flavonoids, thiols present in some foods.
Hidden quality	:	Quality attributes like nutrient content, freedom from adulterants, toxicants that cannot be perceived by the human senses.
EPA	:	Environment protection act.
Enzymatic changes	:	Enzyme catalysed chemical reactions.
Biogas	:	Gas, mostly methane produced by anaerobic fermentation of organic wastes.

1.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Chemical composition, properties;
   - Chemical changes during storage, processing

2. Your answer should include the following points:

   - Scheele, Lavoisier, Liebig, Thenard

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Nutrient requirement of human system
   - Nutrient content of different foods
   - Mixing in suitable proportions

2. Your answer should include the following points:

   - Food formulation containing nutrients in required proportion.

3. Your answer should include the following points:

   - Nutrient content per serving

4. Your answer should include the following points:

   - Bioactive compounds
   - Carotenoids
   - Flavonoids
   - Thiols

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Chlorophyll degradation in spinach and green colour change
   - Pectin degradation and fruit softening

2. Your answer should include the following points:

   - Product factors
   - Environmental factors

3. Your answer should include the following points:

   - Exhausting
   - Nitrogen packing
   - Modified Atmosphere Packaging
   - Controlled Atmosphere storage

Check Your Progress Exercise 4

1. Your answer should include the following points:

   - Starch, sugar, water in milk
   - Paddy husk, saw dust in spices
   - Dates seed, tamarind seed in coffee and tea
   - Mineral acid in vinegar

2. Your answer should include the following points:

   - Pectin, peel oil
   - Biogas

3. Your answer should include the following points:

   - Educating and advising the public on the safe use of food additives.

1.8 SOME USEFUL BOOKS

1. Braverman, J.B.S. (1963) Introduction to the Biochemistry of foods, Elsevier Publishing Company, Amsterdam, London, New York.

2. Meyer L.H. (1969) Food Chemistry, Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.

3. Owen R. Fennema (1976) Principles of food science, Part I-Food Chemistry, Marcel Decker Inc.; New York.

UNIT 2 AN OVERVIEW OF FOOD PHYSIOLOGY

Structure

2.0 OBJECTIVES

After going through this unit, you should be able to:

- know the different stages of growth in the life of fruit;
- understand the physiological changes in fruits and vegetables that take place after harvest;
- tell how senescence can be delayed; and
- mention the structural and compositional changes that take place after harvest.

2.1 INTRODUCTION

Fruits and vegetables are living tissues and remain alive even after harvest. They undergo considerable morphological and bio-chemical changes during growth and following harvest. The visual changes in colour are most prominent indicator of ripening. Many of the quality parameters of harvested produce are affected by pre-harvest factors starting from planting, planting density, irrigation and hormonal treatment. To obtain a produce with good quality all these factors must be controlled.

2.2 MORPHOLOGICAL CHARACTERISTICS

The life of fruit and vegetable crops can be divided into three major physiological stages following germination- growth, maturation and senescence. Growth involves cell division and subsequent cell enlargement, which accounts for final size of the commodity. Maturation usually commences before growth ceases. Growth and maturation are often collectively referred to as development phase. Senescence is defined as the period when anabolic (synthetic) bio-chemical processes give way to catabolic (degradative) processes, leading to ageing and finally death of the tissue. Ripening is considered to begin during the later stages of maturation and to be the first stage of senescence. Development and maturation of fruit are completed only when it is attached to the plant, but ripening and senescence may proceed on or off the plant. But in many plants, a growth after harvest has been observed which is considered undesirable. Elongation and toughening in asparagus, toughening in beans, sprouting in potato and onions are the examples of such growth that occurs after harvest.

Growth and Development

Many tiny individual cells make up the plant body. Each cell consists of living system [protoplasm] and usually a cell wall. The protoplasm is the most significant part of the plant. It is in fact a factory, which manufactures the products of the plant, including the walls of the cell themselves. It is composed of water, salts, sugars, proteins, fats, enzymes, vitamins, growth regulators and a complex of other materials. All of this is organised, through a special portion of the protoplasm [nucleus], into a living unit. As the plants grow and develop, individual cells divide and differentiate into particular kinds of cells and groups of cells, called tissues and organs performing special functions. This addition of cells and the increase in biomass is called growth. An essential organ of a plant is fruit, which develops from another organ of the plant called flower.

Development of fruit and seed

The flower is a group of specialized leaves concerned with the development of structures, which lead to sexual production. A flower consists of four parts:

i) an outer whorl of sepals, usually green, collectively known as the calyx;
ii) petals, usually coloured, which together are called the corolla;
iii) stamens, which produce the pollen grains and male germ cells; and
iv) the pistil, which consists of one or more sections [carpels] bearing the female germ cell and later the seed.

The flower parts are mounted on a portion of the stem known as receptacle. During the formation and development of flowers of any part of the plant, growth regulators play an important role.

A fruit develops from the ovary of pistil. It may consist of a single carpel, as in cherry or of several carpels, as in tomato. Also other parts of the plant may be associated with the fruit, as the enlarged receptacle of the strawberry, the sepals of mulberry and the stem of the pineapple. Attached to the inner edges of the carpel and enclosed within them are the parts (ovules), which develop into seeds.

Initiation of fruit development

Male cells [gametes] from the pollen grains are transferred to the tip (stigma) of the pistil and grow down (through the style) to fertilize the female cells, which are formed in the ovules enclosed in the ovary. The process by which the pollen grains are transferred to the stigma of pistil is called pollination and the process of the fusion of male and female cells (gametes) is called fertilization. The fertilized cell called zygote further grows, divides, differentiates and develops into a new plant (embryo) enclosed in the seed coats. Later, the ovary develops into a fruit. Therefore, the fruit is a matured or ripened ovary. All these processes are carried through the influence of certain growth regulatory compounds called plant-hormones.

Physiology of growth and development

Carbohydrates, which are essential to both plant and animal life are produced in the leaves in a process known as photosynthesis, in which the green colour pigment of the plant (chlorophyll) utilizes light energy to form simple carbohydrate materials (as sugars) from water and carbon dioxide of the atmosphere.

$$6\ CO_2 + 6\ H_2O + 673{,}000\ Cal \leftrightarrow C_6H_{12}O_6 + 6\ O_2$$

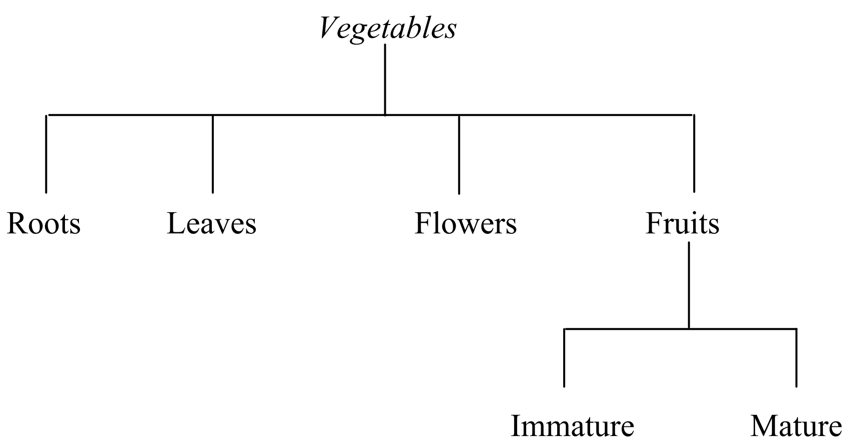
Carbohydrates are moved from the leaves to other parts of the plant. The most important tissues involved in translocation are the xylem and phloem. It is believed that the carbohydrates travel through phloem, while water and minerals travel mainly through xylem.

Food may be stored in various storage organs, such as roots, tubers, rhyzomes, bulbs, corms, fruits and seeds. Storage may occur at different seasons of the year and may in some plants be controlled by the length of the day, the length of the night period and the day & night temperatures. In many plants that live for more than one season (perennials), accumulation in the underground storage organs takes place at a rapid rate in the fall of the year.

Fruits and Vegetables

Fresh fruits, as well as fresh vegetables are essential components of human diet. Both contain a number of nutritionally important compounds, such as vitamins, which cannot be synthesized by the human body; vitamin C is the most important essential nutritive substance found mainly in fruits and vegetables.

The fruits are used as a table commodity whereas the vegetables are usually cooked and then used as food. Some of the vegetables are "fruit-vegetables" and most of the vegetables are the other vegetative organs of the plant that include root, stem, flower, shoot, leaves and associated parts. On the basis of the parts of plants used as food, the vegetables are classified in the following groups:



Similarly, depending on the parts of the ovary wall [pericarp-epicarp, mesocarp and endocarp] developing into flesy and succulent organs of the fruits are classified as under:

Fruits

Drupe Berry Pepo Hesperidum Pome Aggregate type

2.3 POST-HARVEST PHYSIOLOGY OF FRUITS AND VEGETABLES

Fruits and vegetables are highly perishable commodities with active metabolism during the post-harvest period. Proper handling plays an important role in increasing food availability. On removal from the parent plant, vegetative parts, such as fruits, roots, stems etc are deprived of their normal supply of minerals, water, and also in some instances, simple organic molecules [e.g. sugars, hormones] that normally would be translocated from other parts of the plant. Innumerable physiological and bio-chemical processes are initiated and continued in the edible plant tissues at the time of harvest. Although the photosynthetic activity is negligible, most tissues remain capable of transforming many of the constituents already present in them. The diversity of metabolic shifts, which are specific to a given commodity [and often variety] are manifest in events such as 'rotting', 'ripening', 'sprouting', 'scald', 'brown core', 'hard core', 'toughening', and 'yellowing'.

The kind and intensity of physiological activity in detached plants determines their storage longevity. Some plant parts, such as seeds, fleshy roots, tubers, bulbs are morphologically and physiologically adapted to maintain the tissue in a dormant state until environmental conditions are favourable for germination or growth. Metabolic activity, though depressed, is not completely halted in such tissues. Fleshy fruits are unusual in that maturation is followed by a ripening process, which is associated with the development of optimal eating quality.

The diversified visible physiological changes, like sprouting, browning, toughening etc are desirable in some commodities and undesirable in others in relation to the eating quality. Almost all such changes are observed during a most important physiological process called ripening.

Physiology of Ripening

The term "ripening" is generally referred to the physical and bio-chemical changes taking place in the fruits after the cessation of growth till the onset of senescence and decay. The ripening process is dependent upon maturity, since a given stage of development must be attained before ripening proceeds. The process of ripening continues while the fruit is on the tree, but the damage caused by the birds, insects etc makes it uneconomical to allow the fruits to ripen on the tree. Hence, the fruits are usually harvested at the horticulturally mature stage. Fruits being living entities continue to carry on the normal physiological processes resulting in the ripening and finally decay or death of the fruit even after they are separated from the parent plant/tree. Most of the fruits show the ripening changes after harvest with a few exceptions like grapes, which are to be ripened only on the vine, as they do not ripen well after harvest. Since the changes taking place in a fruit during ripening greatly influence the eating quality and the monetary value of the commodity depends on it, a detailed knowledge of the physiology and biochemistry of ripening is desirable for the successful storage and marketability of fruits.

Changes during Ripening of Fruits

Important changes occurring in the fruits during ripening include – 1) Respiration, 2) Transpiration, 3) Carbohydrates, 4) Texture, 5) Flavour, 6) Pigments, 7) Organic acids, 8) Nitrogenous compounds, 9) Tannins, and 10) Enzyme activity.

1. Respiration

Fruits and vegetables of different species differ as to the nature and the rate of the changes taking place but most of them share a respiratory pattern known as "the climacteric". In some fruits, it has been observed that the respiration rate increases with the ripening to a maximum level called as 'Climacteric' peak which is followed by a steady decline in respiration rate, often called senescence. The fruit attains the eating ripe stage at the climacteric peak or sometime after the peak, depending on the species and to some extent temperature and composition of the atmosphere in which the commodity is stored. All other fruits showing no such respiratory pattern are called non-climacteric. In citrus fruits [oranges and lemons], the maturation and ripening progress slowly and the respiratory activity tends to decline following harvesting of commercially mature fruits.

Another important criterion for distinguishing a 'Climacteric fruit' from a 'non-climacteric fruit' is the response to ethylene application. It is well known that ethylene has an enhancing effect on fruit respiration. Biole (1954) showed that a non-climacteric fruit would react to ethylene treatment at any stage of its preharvest or postharvest life, whereas a climacteric fruit will exhibit a respiratory response only if ethylene is available during the pre-climacteric stage, and becomes insensitive to ethylene treatment after the onset of the climacteric rise.

There is a fairly consistent relationship between storage type of fleshy plant tissues and respiration, e.g. peas with a high respiration rate [50 mg CO_2/kg/hr] have a short storage life [1 week at 5°C], while turnips with low respiration rate [6 mg CO_2/kg/hr] have a long storage life [16-20 weeks at 5°C]. The shelf life of a given commodity can be greatly extended by placing it in an environment, which retards the rate of respiration. In other words, the environment modification by refrigeration and carbon dioxide/oxygen (CO_2/O_2) conc. controlled atmosphere will provide a direct effect on the determination of shelf life of the commodities.

Respiratory quotient

From measurements of CO_2 and O_2, it is possible to evaluate the nature of respiratory process. The ratio of CO_2 to O_2 is termed the respiratory quotient [RQ]. This is useful in deducing the nature of the substrate used in respiration, completeness of the respiratory reaction and degree of anaerobic or aerobic process.

2. *Transpiration*

When the fruit is picked and severed from the plant, water no longer flows into the fruit, although the loss of water continues. This process of loss of water in vapour form is known as transpiration. By the time the fruit loses 5% of its original weight, it appears shriveled enough to lose its eye appeal as well as the eating quality. The fruit becomes unattractive because of wrinkled appearance. Hence, this loss of water due to transpiration should be checked in order to maintain its marketability. Judicious application of wax emulsion or other skin coating or pre-packaging with thin paper or cling films could successfully reduce such water losses. On the other hand, in some fruits during ripening, the water content of the pulp increases and the peel decreases, as in the case of banana, which makes the fruit better in eating quality.

2.4 STRUCTURAL CHANGES DURING GROWTH AND RIPENING

A number of changes occur in fruits during ripening. Softening of tissue during ripening is attributed to the changes in cell wall thickness, permeability of plasmalemma, and amount of intercellular spaces. The change in colour of ripened fruit is due to transformation of chloroplast to chromoplast. Although the structure of mitochondria is maintained during growth and ripening, it may degrade in overripe stage. Cuticle deposition increases continuously during ripening but the epidermal hairs either reduce in number or disappear completely.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the different phases of growth in the life of a fruit?

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2. How does softening of tissues occur in fruits during ripening?

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3. Why colour of a commodity changes during ripening?

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4. What is senescence?

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2.5 COMPOSITIONAL CHANGES DURING GROWTH AND RIPENING

Carbohydrate

Sugars are important for pleasing fruit flavour (sugar acid ratio), attractive colour and texture. As the ripening starts these sugars undergo metabolic transformation both quantitatively and qualitatively. Most of the soluble carbohydrates are metabolized completely as the fruit ripens. Pectic substances and cellulose are the reserve carbohydrates that also serve as potential sources of acids, sugars and other respiratory substances during ripening.

In the process of ripening many changes occur in the carbohydrates fraction of fruit during the climacteric and senescence. Green or raw fruit usually contains starch in abundance, but is short in soluble sugars that provides sweetness to it. During ripening, the starch is enzymatically [hydrolysis by alpha- and beta-amylases] converted into sugars. Thus, the major bulk of carbohydrate fraction of a fully ripened fruit consists of sugars. The sugars commonly found in fruits are glucose and fructose [invert sugars] and sucrose.

Organic Acids

The organic acids are among the major cellular constituent undergoing changes during ripening. In most of the fruits there is a considerable decrease in the acidity of fruits during ripening.

The sourness of fruits is due to the presence of organic acids like citric, malic, succinic, tartaric, oxalic etc. These acids usually decide the quality of fruits as the blending of sugar and acids render the fruits tasty, besides flavour. Though these organic acids are present in varying amounts in raw or unripe fruits, but the concentration considerably changes as the fruits ripen. In fruits like oranges, the acids are converted enzymatically into sugars rendering them sweet as they ripen, whereas there is no change in lemons. So they remain sour till they start decaying. But, in some fruits like mangoes, there is a considerable decrease in acidity when the fruits fully ripen. This is probably due to the utilization of these acids in respiration through Kreb's Cycle. Generally, in fruits the total acidity shows a decrease with the increase in ripeness of the fruits.

Amino Acids and Proteins

A major turnover of amino acids in mango takes place during ripening, whereas in carombola it continuously declines. Small increases in protein content were also observed in mango, tomato and avocado.

The nitrogen content of fruit is due to proteins forming insoluble fraction and the soluble fraction comprised of amino acids. The total nitrogen content of fruits at the early stages is high, but with the advancement in growth, shows gradual decrease. This is probably due to the increase in other constituents like water, starch, sugar, organic acids etc. During ripening, the total nitrogen may show a further decrease in some cases.

Lipids

Phospholipids occur in the cytoplasm and in many structural units of plant tissues. They are physiologically more important than neutral lipids in storage organs. Considerable increases in the level of total lipids and fatty acids have been observed in ripening mango in contrast to many fruits and vegetables. However in fatty fruits of avocado the oil composition during maturation remains more or less constant.

Chlorophyll

Disappearance of green colour marks the initiation of ripening in most of the fruits. Chlorophyll content of ripening fruit decreases universally.

Carotenoids

A dramatic synthesis of carotenoids occur during the last step of ripening. It has been reported that the levels of carotenes, free geraniol, mevalonic acid, all precursors of carotene biosynthesis increases progressively during ripening.

Other Pigments

The colour imparted to raw or ripe fruits and vegetables are due to presence of various pigments. The pigments of different tissues are the chlorophyls (green), anthocyanin [reddish to purple], flavonoids [yellow], leucoanthocyanins [colorless], tannins [colorless to yellow or brown], betalains [red], quinones and xanthones [yellowish] and carotenoids [yellow and red].

During storage some of these pigments undergo considerable changes. Carotenoids formation and destruction may be affected by the storage conditions. In certain instances, these reactions are stimulated by O_2, inhibited by light and high temperature. Carotenoids include lycopone, Beta, Gamma carotenes and are synthesized enzymatically in the fruits. Anthocyanin synthesis is stimulated by light and is often affected by temperature. Purple colour of red cabbage intensifies when stored below 10^o C. Chlorophyll degradation is accompanied by synthesis of other pigments as the fruits ripen. Chlorophyll metabolism is markedly influenced by environmental parameters, such as light, temperature and humidity and the effects of these factors are specific for the tissues. For example, light accelerates degradation of chlorophyll in ripening tomatoes and promotes formation of the chlorophyll pigment in cold stored potatoes.

Tannins

The tannins and other polyphenolic constituents are present in abundant quantities in immature, raw or developing fruits. As the maturity and ripening progresses the total polyphenolic content reduces gradually.

Pectic Substances

The most obvious changes during ripening of fruit are the alteration in texture. The plant cell wall is made up of cellulose fibrils embedded in a matrix consisting largely of pectic substances, hemicellulose, proteins, lignins etc and water. Cell wall and middle lamella components increase during development of fruits, but as the fruit ripens the content of soluble pectates and pectinates increase, while total pectic substances decrease.

The cell walls are surrounded by parenchymatous cells, which will absorb water and generate hydrostatic pressure within the living cells. This is called turgor pressure that gives the desirable property of crispness to the commodity. During storage, the loss of moisture due to transpiration and respiration results in the loss of crispness or the turgidity of the commodity. In addition, the changes in the pectic substances – [which form a component of the cell walls of the fruit] – account for the firmness of the fruits. During ripening, the protopectin, which is insoluble and forms, the middle lamella of the cell wall, decreases in quantity and the soluble pectin content rises, thereby making the flesh less firm or soft. A decrease in the chain length and loss of methyl groups of proto-pectin probably occurs during ripening, accounting for the rise in soluble pectin. This is brought about enzymatically mainly by the enzymes pectinase and pectin methyle sterase.

Volatile Products

Each fruit has specific aroma which ripened fruit emanates. Although different fruits vary in nature of volatile compounds, they are emitted in noticeable amount only when the fruit starts ripening. Although the degree of maturity is the main physiological factor affecting aroma production, the aroma composition is also affected by environmental conditions during maturation. In overripe fruits mostly alcohol and esters are formed when fermentation develops.

One of the marked differences between an unripe and ripe fruit is the intensity of flavour of the fruit. The flavour of fruits or vegetables are considered to originate by the presence of basic constituents, such as carbohydrates (particularly mono- and disaccharides], proteins [particularly free amino acids] and fats [triglycerides or their derivatives], as well as vitamins and minerals. These constituents are produced through photosynthetic and related metabolic activities occurring in the commodities. Some volatile compounds may exist in the tissues as such but in some it may be formed enzymatically upon rupture of cells or by microorganisms. Besides ethylene, a number of other volatile odorous constituents like amyl esters of formic, acetic, valeric and caprylic acids have also been identified. These organic emanations produced during ripening of fruits contribute to the aroma of fruits and hence are of considerable importance from the standpoint of fruit quality.

Enzymes

Enzyme action is responsible for many chemical and physical effects during ripening. Softening of fruits, conversion of starch to sugar or vice versa, changes in amino acid content, and enzymes bring changes in color.

Most of the bio-chemical changes occurring in fruits during ripening can be attributed to enzyme reactions. The change from starch to sugar, sucrose to invert sugar or protopectin to pectinic acid are all due to enzymic reactions.

Oxidative enzymes like catalase and peroxidase were shown to have increased to a considerable extent in 'Alphonso' and 'Neelam' varieties of mangoes during ripening as indicated by the higher rate of respiration. Similarly, glycolytic and hydrolytic enzyme activity were also found to increase in ripening mangoes, particularly during climacteric and post-climacteric stages. Transminase activity also increased in mangoes, resulting in the increased amounts of amino acids. Chlorophyllase activity followed the climacteric pattern in bananas, but suggested that the ensuing chlorophyll degradation may not be relevant to ripening. Other enzyme that increases in activity during ripening and following respiratory climacteric is fatty acid synthatase in Avocado fruit.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the effect of planting density on post harvest quality of the horticultural produce?

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2. What is the effect of pre-harvest fertilization on post harvest quality of horticultural produce?

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3. How pre-harvest diseases affect the quality of fresh produce?

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4. What are the effects of low water on fruit quality?

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2.6 LET US SUM UP

The quality of fresh produce depends on many factors during growth and after harvest. The cultural practices followed before harvest has marked effect on fruit quality. A number of physiological and bio-chemical changes take place during growth of the produce that continues after harvest also. Therefore it is important to follow good pre and post harvest practices to extend the shelf life and maintain the quality of horticulture produce.

2.7 KEY WORDS

Morphological changes : Visible changes on the outer surface of the product.

Chemical changes : Changes in composition of the product.

Ripening : The advance stage in the development at which fruit and vegetable are suitable for consumption/ utilization.

Growth : Gradual development towards maturity (increase in size, weight, etc.).

Maturation : Becoming full grown or fully developed.

Senescence : Beginning of final phase in the life of plant.

Cultural practices : A set of operations used for raising a crop in the field.

Planting density : Number of plants per unit area.

Pruning : To cut away or remove unnecessary plant parts.

Thinning : Reduction of population of plants.

2.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:

   - Growth
   - Maturation
   - Senescence

2. Your answers should include following points:

   - Cell wall thickness
   - Plasmalemma
   - Intercellular spaces

3. Your answers should include following points:

   - Chloroplast
   - chromoplast

4. Your answers should include following points:

   - Anabolic
   - Catabolic
   - Aging
   - Death

Check Your Progress Exercise 2

1. Your answers should include following points:

   - Light availability
   - Fruit size

2. Your answers should include following points:

   - Mineral deficiency
   - Mineral toxicity

3. Your answers should include following points:

   - Reduced yield
   - Poor quality

4. Your answers should include following points:

   - Fruit size
   - Splitting
   - Disorders

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UNIT 3 FOOD CONSTITUENTS – CARBOHYDRATES AND LIPIDS

Structure

3.0 OBJECTIVES

The aim of this unit is to introduce you to the chemistry of two major constituents of foods viz. carbohydrates and lipids. After reading this unit you will become familiar with the following aspects:

- *carbohydrates:* Monosaccharides, disaccharides, oligosaccharides and polysaccharides; their occurrence in foods, structure, properties and uses in food industry; and
- *lipids:* Occurrence, chemical properties, fatty acids and their properties and their changes during processing and storage of foods.

3.1 INTRODUCTION

Carbohydrates along with lipids are the primary source of energy for the human system. Carbohydrates are widely distributed in plants and to a limited extent in animals. They under go various changes during processing of foods. Lipids are present both in plant and animal foods. They also undergo physical and chemical changes during processing and storage of foods. Therefore, an understanding of the chemical nature of these substances is very important for preserving foods. In this unit you will be learning the chemical aspects of carbohydrates and lipids.

3.2 CARBOHYDRATES

The first products of photosynthesis in plants are carbohydrates. These compounds, in one form or another, constitute more than one half of the organic matter on earth. The major part of plants is built of carbohydrates while the animal world contains rather limited amounts of them.

3.2.1 Occurrence

Carbohydrates occur in plant and animal tissues as well as in microorganisms in different forms and quantities. They along with oils and fats are the primary source of energy for the human system. In plants, a wide variety of monosaccharides and oligosaccharides occur. Starch is the main storage carbohydrate in root crops and cereals. Similarly, the 'building bricks' or structural carbohydrates of plants are cellulose, hemicellulose and pectin. Some plants, as well as seaweeds and microorganisms produce different types of gums, which are a different group of polysaccharides. Fruits contain predominantly the monosaccharides, glucose and fructose, and the disaccharide sucrose as well as other mono and oligosaccharides in smaller concentrations. Animal foods have mainly glucose and the storage carbohydrate is glycogen. In milk it is almost exclusively the disaccharide lactose. Another group of polysaccharides called dietary fibre (pectin, hemicelluloses, pentosans, etc.) are gaining considerable health importance. Table 3.1 gives an idea of different types of carbohydrates present in different types of foods.

Table 3.1: Average carbohydrate composition and Water content of some foods

Carbohydrate	Cereals		Legumes		Fruits		Vegetables	
	Wheat (%)	Rice (%)	Beans (%)	G.nut (%)	Apple (%)	Orange (%)	Potato (%)	Tomato (%)
Monosaccharides								
D-Fructose	0.1	-	-	-	5.0	1.5	0.1	1.6
D-Glucose	0.1	-	-	-	2.0	2.5	0.1	1.2
Oligosaccharides								
Sucrose	1.0	-	3.0	4-5	3.0	4.6	-	1.0
Polysaccharides								
Starch	71.0	79.0	10.0	15.0	-	-	20.0	-
Pectin	-	-	-	-	0.6	1.3	-	0.3
Water	14.0	13.0	11.0	2.0	84.0	86.0	79.0	93.0

3.2.2 Nomenclature

Carbohydrates were first named according to their natural sources eg. cane sugar, beet sugar, malt sugar, grape sugar etc. Subsequently they got trivial names often from a prefix related to the source followed by the suffix '-ose'. Examples are: fructose (fruit sugar), maltose (malt sugar), lactose (milk sugar), xylose (wood sugar) etc. Though these names do not provide any information on their chemical structure they are still being used widely.

3.2.3 Classification

Carbohydrates are classified into monosaccharides, oligosaccharides and polysaccharides.

Monosaccharides

The simple carbohydrates, the monosaccharides, are neutral, crystallisable substances, which are readily soluble in water. Most of them are sweet covering a wide range of sweetness. Monosaccharides may be divided chemically into polyhydroxy aldehydes (aldoses) and poly hydroxy ketones (ketoses). Depending on the number of constituent formaldehydes (CH2O), these sugars are classified as:

Bioses (CH2O)2;	C2H4O2 (example: glycol aldehyde)
Trioses(CH2O)3;	C3H6O3 (example: glyceraldehyde)
Tetroses (CH2O)4;	C4H8O4 (examples: Erythrose, threose)
Pentoses (CH2O)5;	C5H10O5 (examples: Ribose, rafinose,)
Hexoses (CH2O)6;	C6H12O6 (examples: glucose, mannose, gulose, galactose, fructose, sorbose)

The monosaccharides, which are of primary importance in foods, are hexoses and pentoses.

Hexoses: Five hexoses, three of them aldoses (glucose, mannose and galactose) and two ketoses (fructose and sorbose) are found in the free state in plants. The simple open chain formula of these hexoses (propounded by Fisher) are shown in Figure 3.1.

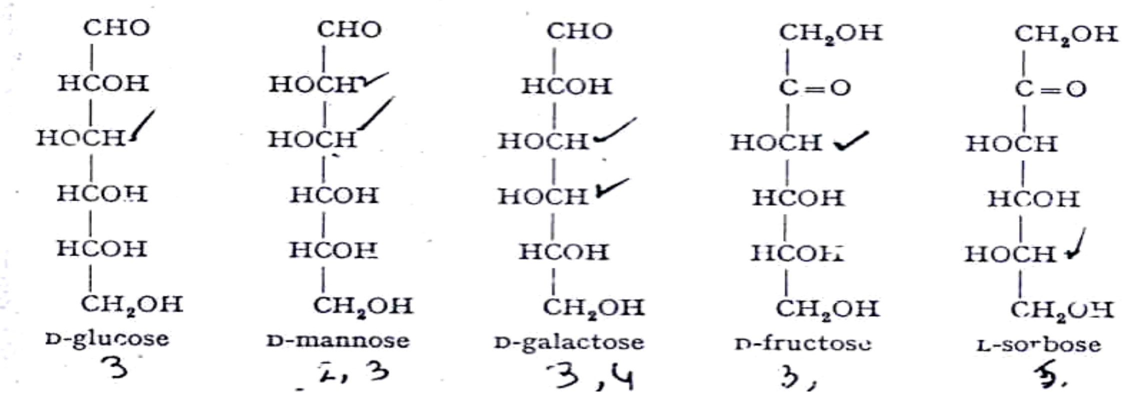

Figure 3.1: Open chain formulae of some hexoses

You will notice that the differences in the structures of these hexoses are in the orientation of the hydroxyl (-OH) groups. Mannose is different from glucose in its configuration at carbon atom 2. Sorbose differs from fructose in its configuration at carbon atom 5. The above formulae of glucose and other sugars show the free carbonyl group and four optically active (asymmetric) secondary hydroxyls. This results in stereoisomerism in sugars. Sugars are designated as D or L. The designation of D or L refers to the two series of sugars, in the D series, the highest number asymmetric carbon has the OH group directed to the right and in the L series this hydroxyl points to the left. The following structures (Figure 3.2) of the simplest sugars, D and L glyceraldehydes explains the series.

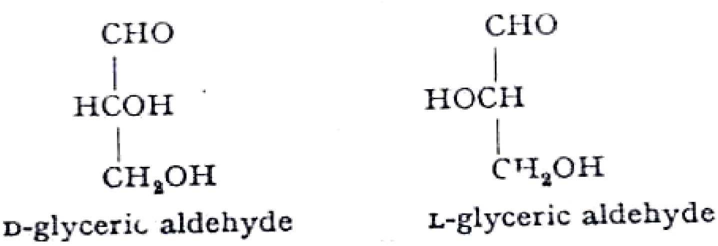

Figure 3.2: D and L glyceraldehydes

Most natural sugars are members of the D series. The open chain formulae of sugars do not explain all the chemical properties. Therefore, various ring structures have been introduced. For example glucose has been assigned a pyranose (6 membered ring) structure and fructose a furanose (5 membered ring) structure.

The simple sugars exhibit a property called optical rotation. You will be learning more on this aspect under polarimetry. In simple terms, optical rotation refers to the property of a substance in solution to rotate plain polarised light to right (dextro rotatory designated by (+)) or to the left (levo rotatory designated by (-)) for example glucose is dextro rotatory and fructose is levo rotatory. A sugar, for example glucose when dissolved in water exist in tautomeric equilibrium between two anomeric forms, each having different degree of optical rotatory power. They are designated as α and β as indicated below (Figure 3.3).

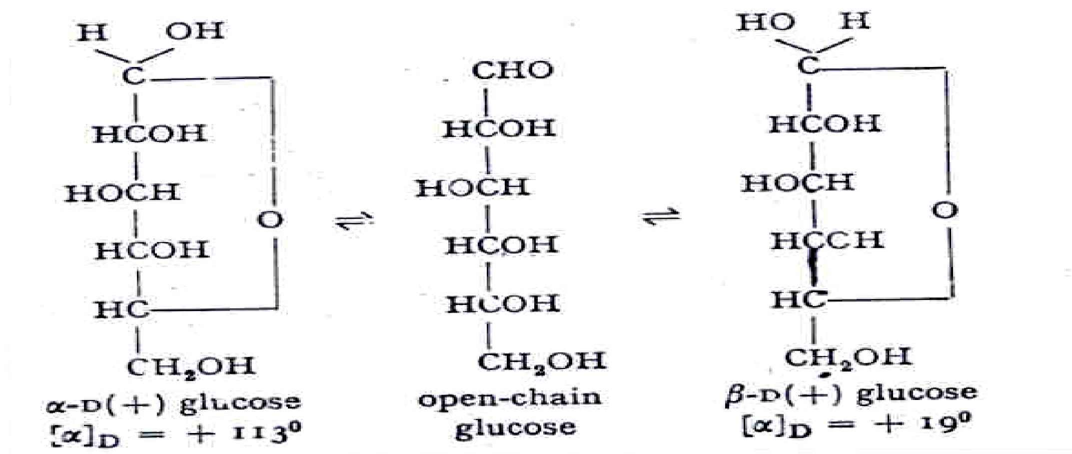

Figure 3.3: α-D and β-D glucose structures

Sugar related compounds present in nature

Amino sugars: Amino sugars usually contain D-glucosamine (2-deoxy-2-amino glucose). They occur as components of high molecular weight compounds such as the chintins of crustaceans and molluscs as well as in certain mushrooms and combined with the ovomucin of egg white.

Glycosides: Glycosides are sugars combined with an alkyl or aryl group. Glycosides are hydrolysed by acid or enzyme to the corresponding sugar and aglicone. Amygdalin is an example of a cyanogenic glycoside, which is present in bitter almonds. Complete hydrolysis of amygdalin yields glucose, benzaldehyde and hydrocyanic acid. Other important glycosides are flavonone glycosides like the citrus bitter principles hesparidin and naringin. Deoxy sugars occur as components of nucleotides like 2-deoxy ribose, which constitute part of deoxy ribo nucleic acid (DNA).

Sugar alcohols: Sugar alcohols occur in some fruits and are produced industrially by reduction of sugars. Reduction of glucose yields sorbitol. Xylitol is a five carbon sugar alcohol. These sugar alcohols are sweet as sugar but are only slowly absorbed in the body and hence are used in diabetic foods. The structure of sorbitol and xylitol are given below (Figure 3.4).

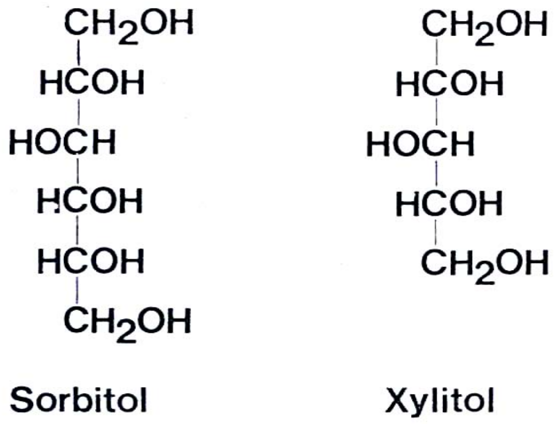

Figure 3.4: Sorbitol and Xylitol

Oligosaccharides

Oligosaccharides are water-soluble polymers of a few condensed monosaccharides. Those most commonly found in foods are homopolymers of D-glucose (e.g. maltose) or heteropolymers of D-glucose condensed with D-fructose (e.g. Sucrose) or D-glucose with D-galactose (e.g. lactose). The above oligosaccharides are di-saccharides. Raffinose a trisaccharide is found in sugar beet. It is a polymer of D-glucose, D-fructose and D-galactose.

Sugars and sweeteners: Sucrose is the most widely used natural sweetener. Of all the sugars, D-fructose is known to be the sweetest. It is customary to compare the degree of sweetness of different sweeteners to sucrose to which the number 100 has been assigned. Fructose has sweetness value of 173.3 and glucose 74.3. Therefore, the hydrolysis product of sucrose (invert sugar containing glucose and fructose) has sweetness value of 173.3+74.3/2 = 123.8. The relative sweetness of various sweeteners is given in Table 3.2.

Table 3.2: Degree of sweetness of various sweeteners

Sweetener	Degree of Sweetness
Sucrose	100
Fructose	173.3
Glucose	74.3
Corn Syrup	30.0
Honey	97.0
Saccharin	30,000 – 50,000
Dulcin	20,000

Corn sweeteners: Cornstarch can be hydrolysed by acid or acid-enzyme process to yield smaller and smaller fragments and ultimately glucose (dextrose). The degree of depolymerisation is expressed as dextrose equivalent (D.E.) which is defined as the amount of total reducing sugars expressed as dextrose and calculated as a percentage of the total dry matter.

Glucose syrup is a concentrated solution of sugars obtained by hydrolysis of starch and having D.E. of 20 or more. When a product has a D.E. of less than 20, it is called maltodextrins. Glucose can be isomerised to fructose by an enzyme called isomerase. As fructose is sweeter than glucose, High Fructose

Syrup (HFS) which is sweeter than glucose syrup is prepared using the enzyme.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define monosaccharides, oligosaccarides and polysaccarides.

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2. Give three examples of hexoses.

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3. Explain optical rotation.

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4. Give two examples of glycosides.

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5. Give two examples of disaccarides.

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6. What is invert sugar? Why invert sugar is sweeter than sucrose?

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Polysaccharides

Polysaccharides are polymers of the simple mannoses, hexoses or pentoses, which occur in nature in different forms. Unlike the sugars they are not sweet and are mostly insoluble in water. Examples of polysaccharides found in nature are cellulose, starch, pectin and chitin.

Cellulose: The structural materials of the entire plant world consist largely of cellulose. Cotton is essentially pure cellulose. On hydrolysis cellulose yields glucose meaning that it is a polymer of glucose. Celluloses from different sources have molecular weight ranging from 100,000 to 2,000,000.

Cellulose is insoluble in water and most solvents and is relatively resistant to hydrolysis by dilute acids. Man and carnivorous animals are unable to digest cellulose, since they lack the necessary enzymes for its breakdown in their intestines. However, many microorganisms and protozoa are able to break it down. Ruminants are able to digest cellulose because of the presence of these microorganisms in their intestines. Though cellulose has only indirect food value (cellulose feed is converted to meat by animals) it has many other uses like in the manufacture of paper, textiles, explosives, paint, etc.

Starches: Starch is the most important polysaccharide and is distributed widely in nature as a reserve material in plants. It contributes more calories to the normal human diet than any other single nutrient.

Starch from different sources consists of granules of different shapes and sizes. Generally all starches contain two types of molecular structures namely amylose and amylopectin.

Amylose is a long straight chain of glucose units, which reacts with iodine to give blue colour. Amylopectin is a branched molecule consisting of a number of amyloses, which reacts with iodine to give reddish brown colour.

Amylose and amylopectin content of starches from different sources vary. In the most common starches such as corn, rice and potato, amylose is the minor component and represents about 17 to 30% of the total. Some varieties of pea and corn starch may have as much as 75% of amylose.

Starch granules naturally present in plants are completely insoluble in cold water and upon heating they will start to swell and the gelatinisation temperature. Continuation of heating above this temperature results in further swelling of the granule and the mixture becomes viscous and translucent. When such a paste is agitated, the swollen starch granule structure breaks down and the viscosity greatly reduces. When a cooked starch paste is cooled, it may form a gel or under conditions of slow cooling, the linear compound may form a precipitate. This phenomenon called retrogradation. The staling of bread is ascribed to retrogradation of starch. The rate of staling is temperature dependent. Retrogradation is faster at low temperature and hence bread stales more quickly in the refrigerator than at room temperature. Freezing, however, prevents staling and retrogradation of starch.

The functional properties of starches such as its cooked paste viscosity play an important role in their food applications. Cereal starches (corn, wheat, rice and sorghum) form viscous short bodied pastes which set to opaque gels on cooling. Root and tuber starches (potato, cassava or tapioca) form highly viscous paste, which are clear but on cooling become weak gels. Waxy starches (waxy corn and rice) form heavy bodied springy pastes. These pastes are clear and have a low tendency for gel formation. High amylose starch requires high temperature for gelatinisation and gives short bodied paste which form very firm opaque gels on cooling. These are suitable for film formation, which find application in coating of fruits as edible coats. In order to impart the desired functioning properties, starches can be modified by certain chemical or enzymes treatments. Such starches are called 'modified starches'.

Pectic substances: Pectic substances occur as constituents of cell walls. In the native form, they are bound to cellulose as protopectin. Mild acid hydrolysis of protopectin yields pectin or pectinic acid. Pectinic acids are collidal, galacturonic acids containing more than negligible proportion of methyl ester groups. Pectins are water dispersable pectinic acids having varying methyl ester contents that are capable of forming gels with sugar and acid under suitable conditions. Pectic acids are composed mostly of colloidal polygalacturonic acids and are essentially free from methyl ester groups.

A linear chain of anhydro-D-galacturonic acid units is the basic structure of pectic substances. In an earlier section you have studied the structure of galactose. When the –CH2OH of a hexose is replaced by –COOH it becomes an uronic acid. The chemical structures of some uronic acids are shown in Figure 3.5.

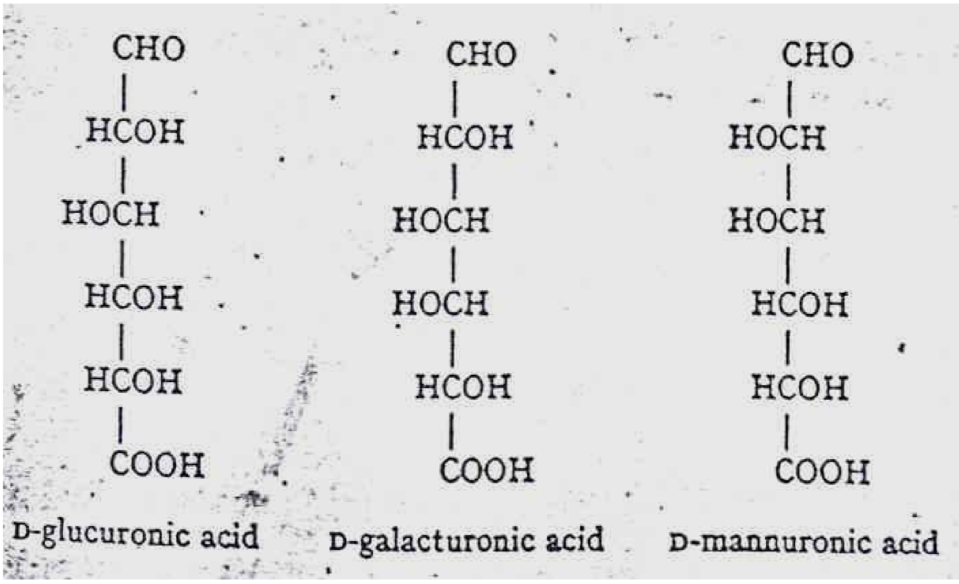

Figure 3.5: Uronic acids

A number of enzymes have been found to catalyse the various stages of pectin break down. You are familiar with softening of fruits during their ripening. It is due to the break down of pectin by the pectin degrading enzymes present in the fruits. There are two major types of pectin degrading enzymes. One is called pectin esterase (PE) or pectin methyl esterase (PME). This enzyme removes the methoxyl groups from the pectin molecules thereby reducing the viscosity of pectin solution and destroys its gelling property. The other enzyme is called polygalacturonase (PG), which breaks down pectinic acid chain into smaller fragments. For PG to act on pectin, the pectin molecule has to be initially demethylated to pectic acid by PME

Pectin as a jellifying agent: The most important use of pectin in food is based on its ability to form gels and it is therefore widely used in the manufacture of jams, jellies and marmalades. Depending on the degree (extent) of methylation (DM) of the carboxyl groups in pectin, they are classified into high and low methoxyl pectins (HMP and LMP). Generally, pectin having more than 50% methylated carboxyl groups (DM more than 50) are called high methoxyl pectin (HMP). HM pectins form gels with sugar and acid. For a good jelly, the sugar content should be in the range of 65–70% and pH 2.8 to 3.2. When the degree of methylation is below 50, the pectin is called low methoxyl pectin (LMP). Low methoxyl pectins form gels at a lower level of sugar but with divalent cations especially calcium. They can be gelled over a much wider pH range also. Therefore, LMP is used in preparing low sugar diabetic jams and jellies.

Citrus peel and pomace as well as apple pomace are good sources of pectin. Therefore, these raw materials are usually used for the manufacture of pectin.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the difference between cellulose and starch?

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2. What is the basic molecule in pectin?

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3. What is the difference between high and low methoxyl pectins?

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Gums: The term gum has been applied to many substances, both hydrophilic (water attracting) and hydrophobic (water repelling) that has gummy characteristics. Sometimes hydrophobic gums are called resins. Gums are essentially polysaccharides and are of plant and microbial origin.

Plant gums: Plant gums can be classified as seed gums, plant exudate gums and seaweed gums. They find wide food applications as stabilisers, thickeners, foam stabilisers, clarifying agents, flavour fixing agents, etc. Table 3.3 gives details of some vegetable gums used as food additives.

Table 3.3: Properties and use of some vegetable gums

Name and Source	Properties
Seed gums	
Guar gum *(Cyamopsis tetra gonoloba)*	Non ionic, heat stable, hydrates in cold water
Locust bean gum *(Ceratonia siliqua)*	Like guar but heat required for maximum hydration and viscosity.
Plant exudate gums	
Gum Arabic *(Acacia senegal)*	Highly soluble, low viscosity, clear solution.
Seeweed extracts	
Agar *(Rhodophyceae)*	Forms strongest and most stable gel. Gels are transparent and reversible upon heating and cooling.
Carrageenans *(Rhodophyceae)*	Anionic, forms stable complexes with proteins and other gums.
Alginates *(Phaeophyceae)*	Anionic, widely variable viscosity properties in acid and salt, forms gels and films

Microbial gums: Polysaccharides produced by microorganisms are finding wide food applications today. Dextran gums are produced by the action of micro- organisms like *Leuconostoc mesenteroides* on sugar syrup. They are readily soluble in water and have typical characteristics of a hydrocolloid like plant gums. Xanthan gum is produced by the action of *Xanthomonas campestris* on sugar containing medium. This gum consists of condensed D-glucose, D-mannose and D-glucuronic acid groups.

3.2.3 Chemical Reactions of Carbohydrates

Several of the chemical reactions of carbohydrates affect the food quality. During food processing operations, especially heat processing like sterilisation, cooking and dehydration, carbohydrates undergo several changes. Part of the non reducing sugars (like oligosaccharides) and polysaccharides hydrolyse to form reducing sugars. The carbonyl groups of the reducing sugars combine with the basic amino groups of proteins, peptides and amino acids to form sugar – amine compounds which undergo a series of reactions called Maillard reactions to produce dark coloured compounds and sometimes off flavour. This reaction is also referred to as non-enzymatic browning reaction to distinguish the enzyme mediated browning we observe, for example in cut fruits like apple where it is oxidation of some phenolic compounds.

Sugars alone in the absence pf amino acids can also cause browning or blackening. At very high temperatures (above 100°C) reducing sugars condense with each other to form higher oligosaccharides and cyclic compounds. Such darkening reaction of sugars is called caramalisation.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give three examples of plant gums.

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2. Explain microbial gums.

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3. Explain Maillard reaction.

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3.3 LIPIDS

Of the three most important nutrients, carbohydrates, proteins and edible fats, the latter belongs to a large class of very diverse substances called lipids. They can be classified into three main groups, their common property being that all contain fatty acids.

3.3.1 Occurrence and Classification

a) Fats and oils: They consist of triglycerol esters of fatty acids (designated here as F1, F2, F3) of the following general formula (Figure 3.6), which easily undergo hydrolysis forming glycerol and fatty acids.

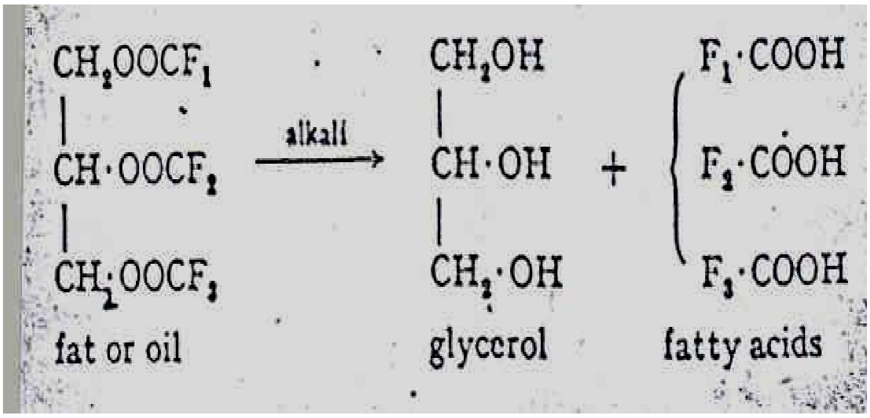

Figure 3.6: Alkali hydrolysis of fats and oils

Liquid fats are commonly referred to as oils.

b) *Waxes:* They consist of fatty acids esterified by monohydric long chain alcohols such as melyssil alcohol (C30H61OH) in bees wax.

c) *Phospholipids:* They are complex compounds in which glycerol or other alcohols are esterified partly by fatty acids and partly by phosphoric acid and by basic nitrogen compounds.

Lipids occur in all parts of plants and animal tissues. However, they are abundantly found in specific fat tissues, seeds and nuts (Table 3.4).

Table 3.4: Fat content of some foods

Food	Fat (%)
Cereals	
Maize	3.6
Rice	0.6
Wheat	1.5
Wheat germ	7.4
Pulses	
Bengal gram	5.3
Black gram	1.4
Green gram	1.3
Peas, dried	1.1
Soyabean	19.5
Leafy vegetables	
Amaranth	0.5
Cabbage	0.1
Drumstick leaves	1.1
Nuts	
Almond	58.9
Groundnut	40.1
Sesame seed	43.3
Fruits	0.1
Apple	22.4
Avocado (Butter fruit)	

Seafoods	
Bombay duck	0.7
Sardine (High fat)	14.3
Meat	
Poultry meat	0.6
Mutton	13.3
Egg (hen)	13.3
Dairy products	
Milk (cow)	3.6
Milk (buffalo)	8.8

3.3.2 Fatty Acids

Even number straight chain saturated and unsaturated fatty acids makeup the greatest portion of the fatty acids of the natural fats. The fatty acid composition of fats and oils has great bearing on human health.

Saturated fatty acids: These are straight chain acids with an even number of carbon atoms from C_2 to C_{26}. Their general formula is:

$$CH_2\,(CH_2)_n\,COOH$$

Where n is the number of – CH_2 groups.

The most widely distributed fatty acids in oils and fats are palmitic, lauric and stearic. It is customary to designate fatty acids by the number of carbon atoms they have. For example 16:0 refers to a fatty acid with 16 carbon atoms and zero refers to the number of double bonds (unsaturated carbon atoms). The chemical formulae of the three fatty acids are given below:

Lauric acid (12:0) : $CH_3.\,(CH_2)_{10}.COOH$
Palmitic acid (16:0) : $CH_3.(CH_2)_{14}.\ COOH$
Stearic acid (18:0) : $CH_3\ (CH_2)_{16.}\ COOH$

Unsaturated fatty acids: The most widely distributed unsaturated fatty acids in oils and fats are given below:

Oleic acid (18:1) : CH3.(CH2)7 CH=CH.(CH2)7. COOH
Linoleic acid (18:2) : CH3.(CH2)4 (CH:CH.CH2)2. (CH2) 6.COOH
Linolenic acid (18:3) : CH3.CH2. (CH: CH.CH2) 3. (CH2) 6.COOH
Archadonic acid (20:4) : CH3.(CH2)4. (CH: CH.CH2) 4. (CH2)2.COOH

3.3.3 Properties of Fats and Oils

Lipids are water insoluble but soluble in organic solvents such as petroleum ether, hexane, chloroform etc. Certain physical and chemical properties of fats and oils help in identifying them. Fats do not melt sharply but soften over a range of temperatures and therefore melting point is not a very reliable technique to identify a fat. However, it provides some information on its identity. Different oils and fats have refractive indices with narrow variations. Therefore, refractive index measurement helps in testing the purity. Their smoke point, flash point and fire point characterizes fats and oils. The smoke point is the temperature at which a fat or oil gives off a thin bluish flame. The flash point is the temperature at which the mixture of vapour with air will ignite and the fire point is the temperature at which the substance will sustain continued combustion.

Chemical properties: A number of chemical tests have been evolved to identify fats and oils and to detect adulteration. All oils and fats show some range of values and therefore sometimes more than one test is necessary.

Reichert–Meissl number: It is a measure of the amount of water soluble volatile fatty acids. It is defined as the millilitres of 0.1N alkali (such as potassium hydroxide) required to neutralise the volatile water soluble fatty acids in a 5g sample of fat. The common volatile water soluble fatty acids are butyric (C4) and caproic (C6) and caprylic (C8) acids. Reichert-Meissl number is particularly valuable in detecting adulteration in butter.

Saponifaction number: It is defined as the number of milligrams of potassium hydroxide required to saponify one gram of fat or oil. When potassium hydroxide reacts with a triglyceride, 3 moles of potassium hydroxide react with one molecule of fat. If the triglycerides contain low molecular weight fatty acids, the number of molecules present in 1 gram sample of fat will be greater than if the fatty acids have long carbon chains and higher molecular weights. The fats with the low molecular weight fatty acids will consequently have a higher saponifaction number. For example, butter with its unusually high percentage of butyric acid has the highest saponification number.

Iodine number: It is the number of grams of iodine absorbed by 100 g of fat. The double bonds found in the unsaturated fatty acid react readily with iodine or certain iodine compounds to form an addition compound even while the fatty acid is combined with glycerol in fat. The iodine number is therefore, a measure of the extent of unsaturation of the fatty acids in a fat.

Rancidity: We are familiar with the development of rancid smell in oils on storage. The process of auto oxidation and the resulting deterioration in flavour of fats and fatty acids are often described by the term ‘rancidity’. Temperature, moisture, the amount of air in contact with the oil or fat, light as well as the presence or absence of antioxidants influence rancidity development. Usually rancidity is referred to oxidative deterioration, but in many fats especially butter, rancidity refers usually to hydrolytic changes resulting from enzymatic activity. In general animal fats develop rancidity faster than vegetable or seed fats.

Oxidation of fats and oils is usually referred to as auto oxidation, because the rate of oxidation increases as the reaction proceeds. Fats and oils containing unsaturated fatty acids are generally susceptible for auto oxidation, though in practice deviations are possible due to the presence of natural antioxidants in them. The reaction products of auto oxidation of oils and fats are peroxides, hydroperoxides, aldehydes and short chain fatty acids which are responsible for the off flavour. **Peroxide value** of fats measures the extent of rancidity development. It is based on the amount of iodine released from potassium iodide by peroxides.

Lypolysis: Fats and oils also become rancid due to lypolysis. The ester linkages of lipids are subject to hydrolysis resulting from enzymes, heat, or chemical reactions. These reactions are collectively known as lypolysis, lypolytic rancidity or hydrolytic rancidity. The free fatty acids that develop during storage and processing of oil seeds and animal tissues must be removed by a refining process. The lower free fatty acids being volatile by steam can be removed by steam distillation under vacuum while the remaining fatty acids are converted by means of sodium or potassium hydroxides into soaps by settling or centrifugation.

Antioxidants: Antioxidants are nothing more than substance with preferential ability to oxidize namely certain compounds, which will oxidize prior to the substances that are being protected. They are both water soluble and fat soluble. For protecting fats, oils and fatty foods, fat-soluble antioxidants are required. Butylated hydroxy anisole (BHA), Butylated hydroxy toluene (BHT) and esters of gallic acid are common antioxidants for this category of foods. Many naturally occurring substances also function as antioxidants. Most prominent are tocopherols. Their presence in natural vegetable oils is the cause for stability of such oils.

Hydrogenation: The physical requirement of many fats used in foods is generally different from those of natural fats and oils. Hydrogenation, the direct addition of hydrogen to double bonds of fatty acids is used to modify vast quantities of fats and oils. Vanaspati is an example of hydrogenated fat. Close control of hydrogenation results in highly specific results. For example, salad and cooking oils can be improved by controlled hydrogenation. Hydrogenation of fats and oils is achieved by mixing them with hydrogen at elevated temperature in the presence of a suitable catalyst, the most common being nickel.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give an example of a fruit containing high level of fat.

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2. What are the hydrolysis products of fats and oils?

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3. What is the difference between saturated and unsaturated fatty acids? Give two examples for each.

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4. Define Reichert-Meissl number and iodine number of fats and oils.

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3.4 LET US SUM UP

Carbohydrates are widely distributed in nature. They are grossly classified into monosaccharides, oligosaccharides and polysaccharides. Simple sugars like glucose and fructose are monosaccharides. Sucrose (cane sugar) is the most important disaccharide.

Unlike monosaccharides and oligosaccharides, polysaccharides like cellulose and starches are insoluble in water. Both cellulose and starches are made up of glucose units, but differ in their number of glucose units and their nature of bonding.

Sugars undergo browning reactions during processing and storing. Nonenzymatic browning reactions (Maillard reactions) are initiated mainly due to the reaction between reducing sugars and their amino acids.

Plant gums are also a class of polysaccharides. They have many food and industrial applications.

Lipids are distributed widely in plant and animal foods. They are classified into oils and fats, waxes and phospholipids. Oils and fats on hydrolysis yield fatty acids and glycerol. Fatty acids can be saturated or unsaturated. There are different methods to find out the degree of unsaturation in fats and oils. Unsaturated fatty acids in fats and oils are responsible for rancidity development. Adding antioxidants to fats and oils and fatty foods can prevent development of rancidity.

3.5 KEY WORDS

Monosaccharides : Simple sugars or monoses, readily soluble in water and most of them are sweet to taste.

Hexoses : Six carbon sugars like glucose and fructose.

Oligosaccharides : Water soluble polymers of a few condensed monosaccharides.

Disaccharides : Polymers of two condensed monosaccharides like sucrose, maltose and lactose.

Degree of sweetness (DS) : Sweetness scale in which sweetness of sucrose is assigned the number 100. Fructose has DS of 173.3 and saccharin 30,000 to 50,000.

Polysaccharides	:	Polymers of simple sugars having high molecular weights. Examples are cellulose and starch.
Pectic acid	:	Unmethylated poly galacturonic acid.
High and low methoxyl pectins	:	Pectic acid in which more than 50% of the carboxyl groups are methylated and in which less than 50% carboxyl groups methylated are called high and low methoxyl pectins respectively.
Gums	:	Complex polysaccharides of plant and microbial origin having gummy characteristics.
Maillard reaction	:	Reaction between reducing sugars and amino acids leading to brown compounds.
Rancidity	:	Development of rancid odour in oils and fatty foods on storage.

3.6 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answers should include the following points:

1. Simple sugars, polymers of few monomers, water soluble, sweet. Polymers of simple sugars of large molecular weight.
2. Glucose, fructose, mannose, sorbose.
3. Rotation of plain polarised light.
4. Amygdaline, naringin.
5. Sucrose, maltose, lactose.
6. Sucrose hydrolysis, fructose sweeter than glucose.

Check Your Progress Exercise 2

Your answers should include the following points:

1. α and β linkages, degree of polymerisation.
2. Galacturonic acid
3. Degree of methylation of pectic acid.

Check Your Progress Exercise 3

Your answers should include the following points:

1. Guar gum, gum Arabic, carrageenans.
2. Xanthan, dextran.
3. Sugar – amino acid reaction.

Check Your Progress Exercise 4

Your answers should include the following points:

1. Avocado
2. Glycerol and fatty acids
3. Double bonds, palmitic, stearic, oleic, linolenic
4. Water soluble volatile fatty acids
5. Degree of unsaturation
6. Oxidation of unsaturated fatty acids

3.7 SOME USEFUL BOOKS

1. Owen R. Fennema, (1976) Principles of food science, Part I-Food Chemistry, Marcel Decker Inc.; New York.

2. Meyer L.H. (1969) Food Chemistry, Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.

3. Braverman, J.B.S. (1963) Introduction to the Biochemistry of foods, Elsevier Publishing Company, Amsterdam, London, New York.

UNIT 4 FOOD CONSTITUENTS – PROTEINS, ENZYMES AND WATER

Structure

4.0 OBJECTIVES

After reading this unit, you will be able to answer:

- what are proteins and amino acids? How proteins are classified? Protein structure, their Denaturation and the role of protein and amino acids in non-enzymatic browning. Proteins of plant, seeds, marine and animal origin. Classification and properties of enzymes etc.; and
- you will also learn the importance of the state of water in foods in food preservation, freezing of water, water quality and standards and water analysis.

4.1 INTRODUCTION

Unlike the other two major nutrients viz., carbohydrates and lipids that are essentially energy sources, proteins constitute the main structure of the animal and human body. These constituents characterised by their nitrogen content are involved in many vital processes intricately associated with all living matter. Some proteins function as biocatalysts (enzymes). There are different types of enzymes in all living systems. They catalyse most of the biological reactions. As enzymes have high degree of specificity, mostly one enzyme can catalyse only one reaction. Several enzymes like amylase, invertase, glucose oxidase, Pectinases, proteases, find application in food processing.

Water is an essential constituent of foods. The state of water in foods has great bearing on food preservation. The physical, chemical and microbiological quality of water used in food processing operations should conform to certain minimum standards.

4.2 PROTEINS

Protein is one of the three major basic nutrients required for growth and development, the other two being carbohydrates and lipids. The word protein was coined from the Greek proteios, which means 'of the first rank'. Proteins are very complex organic substances, constitute the main structure of the animal and human body. These macromolecules, characterized by their nitrogen contents are involved in many vital processes intricately associated with all living matter. Some proteins function as biocatalysts (enzymes) and hormones to regulate chemical reactions within the body.

4.2.1 Amino Acids

Amino acids are the building blocks of proteins. Proteins are polymers of some 20 amino acids joined together in different proportions and sequences. Most amino acids have general chemical structure as given in Figure 4.1.

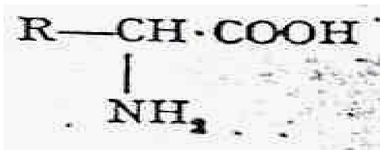

Figure 4.1: General chemical structure of amino acids where R= aliphatic, aromatic, heterocyclic etc. groups

They have both amino group and acidic carboxyl group. In proteins the amino acids are joined together by peptide bond (-CO-NH-) (Fig.2) i.e. The carboxyl group of one amino acid is linked with the amino group of the second amino acid with elimination of H_2O.

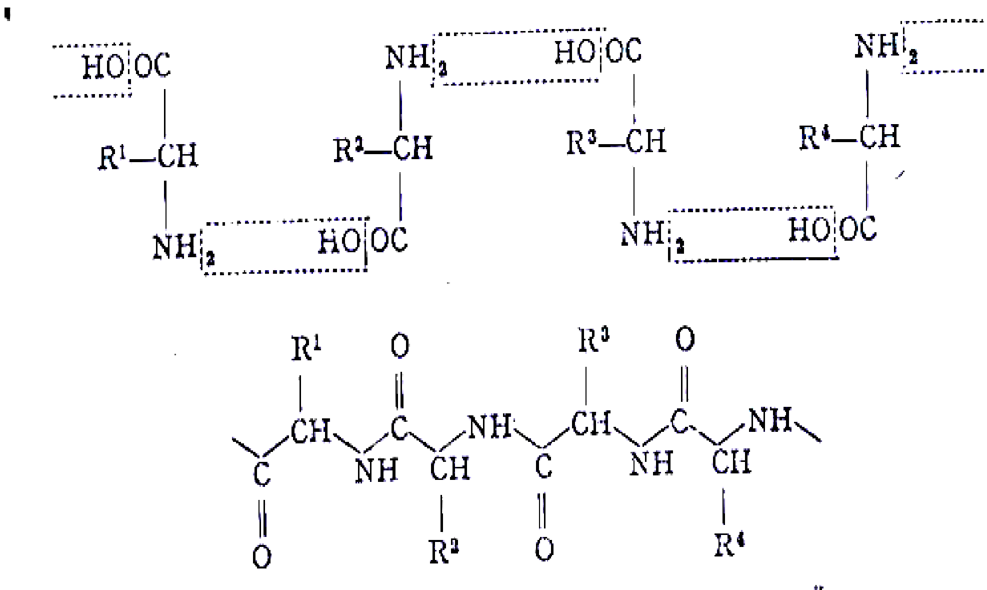

Figure 4.2: The peptide bond

Amino acids found in nature are classified into six groups: viz.,

1. Aliphatic mono amino mono carboxylic amino acids e.g. glycine, alanine, valine, leucine, isoleucine, serine and threonine.

2. Sulphur containing amino acids e.g. cysteine, cystine and methionine.

3. Aliphatic mono amino dicarboxylic amino acids, e.g. aspartic acid and glutamic acid.

4. Aliphatic basic amino acids, e.g. lysine, arginine and histidine.

5. Aromatic amino acids, e.g. phenylalanine and tyrosine.

6. Heterocyclic amino acids, e.g. triptophan and proline.

Of the above amino acids, eight for adults and ten for children are considered essential or indispensable for the human diet. They are: lysine, triptophan, phenylalanine, threonine, valine, methionine, leucine and isoleucine. The amount of these amino acids present in a protein and their availability determine the nutritional quality of the protein. In general animal proteins are of higher quality than plant proteins. However, plant proteins can be upgraded nutritionally by judicious blending. That is why, traditionally people consume a variety of pulses. Egg protein is one of the best quality proteins and is considered to have a biological value of 100. It is widely used as a standard and protein efficiency ratio (PER) values are sometimes based on egg white as a standard. Cereal proteins are generally deficient in lysine and threonine. Soya is a good source of lysine but deficient in methionine. Cottonseed protein is deficient in lysine and groundnut protein in methionine and lysine. The protein of potato although present in small quantity is of excellent quality and is equivalent to that of whole egg.

4.2.2 Protein Classification

Proteins are divided into two main groups namely simple and conjugated and derived proteins.

Simple Proteins

Simple proteins yield only amino acids on hydrolysis and include the following classes:

a) *Albumins:* They are soluble in neutral salt free water. Usually these are proteins of relatively low molecular weights. E.g. egg albumin, lactalbumin and serum albumin in the whey proteins of milk, leucosin of cereals, legumelin in legumes.

b) *Globulins:* They are soluble in salt solutions and almost insoluble in water. E.g. Serum globulins and β-lacto globulin in milk, myosin and actin in meat, glycinine in soybean.

c) *Glutelins:* Soluble in very dilute acids or bases, insoluble in neutral solvents. E.g. Wheat glutelin and oryzenin in rice.

d) *Prolamins:* Soluble in 50-80% ethanol and insoluble in water. E.g. Gliadin in wheat, zein in corn and hordein in barley.

e) *Scleroproteins:* Insoluble in water and neutral solvents and resistant to enzymatic hydrolysis. These are fibrous proteins serving structural and binding purposes. Gollagen of muscle tissue, elastin of tendens, creatin of hair and fibroin of silk are examples.

f) *Histones:* Basic proteins containing a large number of basic amino acids like lysine and arginine. Soluble in water and precipitated by ammonia.

g) *Protamins:* Strongly basic proteins of low molecular weights. They are rich in arginine. E.g. Cupein from herring, and scombrin from mackerel.

Conjugated Proteins

Conjugated proteins contain an amino acid part combined with a non protein material such as lipids, nucleic acid, carbohydrates and others. Some of the conjugated proteins are:

1. *Phospho proteins:* They constitute an important group including many major food proteins. This group includes casein of milk and the phosphoprotein of egg yolk.

2. *Lipoproteins:* These are combination of lipids with proteins and have excellent emulsifying capacity. Lipo protein occurs in milk and egg yolk.

3. *Nucleoproteins:* These are combination of nucleic acids with protein. They are found in cell nuclei.

4. *Glycoproteins:* These are combination of carbohydrates with protein. Ovomucine of egg white is an example.

5. *Chromo protein:* These are proteins with coloured prosthetic groups. Hemoglobin, myoglobin, chlorophyll and flavo proteins are examples.

4.2.3 Protein Structure

The Primary structure of proteins is related to the peptide bonds between the component amino acids and also to the amino acid sequence in the molecule. A peptide chain may become involved in hydrogen bonding between amide nitrogen and carbonyl oxygen. These bonds may be formed between different areas of the same polypeptide chain or between adjacent chains. Such bonds establish the secondary structure of proteins, which may be of helical or sheet form.

The tertiary structure of protein is established when the chain are folded into compact structures stabilized by hydrogen bonds, disulphide bridges, etc. Large molecules may form quaternary structures by association of sub units.

4.2.4 Protein Denaturation

Denaturation is a process of change in structure of proteins without breaking covalent bonds. The process is peculiar to proteins and affects different proteins to different degrees. Denaturation can be brought about by a variety of agents of which the most important are heat, pH, salts and surface effects. The destruction of enzyme activity by heat is one of the most important operations in food processing. You are familiar with the coagulation or hardening of egg white on heating it. It is due to denaturation of egg albumin. Freezing can also cause protein denaturation as in the case of fish, which becomes tough on freezing and thawing. Milk protein casein and gelatin are examples of proteins, which can be boiled with out apparent denaturation.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the different groups of amino acids.

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2. Define albumins and globulins.

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3. What are phosphoproteins and lipoproteins?

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4.2.5 Non-Enzymatic Browning

Browning of several foods is familiar to all of us. Browning of potato chips, brown crust formation on bread and cakes, browning of evaporated milk, browning of jams, candies, fruit juice concentrates etc. are all examples of non-enzymatic browning. The browning reaction can be defined as the sequence of events, which begins with the reaction of the amino group of amino acids, peptides or proteins with a glycosidic hydroxyl group of sugars and terminates with the formation of brown nitrogenous polymers or melanoidins. While some browning reactions like brown crust formation on bread and cake are desirable, most others are undesirable and may accompany formation of off flavoured compounds.

Methods of preventing browning could consist of measures indented to slow the reaction rates such as control of moisture, temperature or pH or removal of an active intermediate. Generally it is easy to use an inhibitor. One of the most effective inhibitors of browning is sulphur dioxide. It is known that sulphur dioxide can combine with the carbonyl group of an aldose to give an addition compound thus blocking further transformations leading to formation of dark coloured compounds.

$$NaHSO_3 + R\text{-}CHO \rightarrow RCHOHSO_3Na$$

However, as sulphite can destroy the vitamin thiamine, it is not desirable to use it to inhibit browning in foods, which are good sources of this vitamin.

4.2.6 Protein from Different Sources

Human requirement of proteins is met from both animal and plant sources.

Proteins of Animal Origin

A typical adult mammalian muscle contains 18-20% protein. Muscle proteins are categorized on the basis of their origin and solubility as sarcoplasmic, myofibrillar and stroma proteins. Protein content of milk ranges from 3 to 4%. Buffalo milk has slightly higher level of protein. Milk proteins are grossly divided into casein and whey protein, the average ratio being 80:20. Egg contains on an average 11% shell, 31% yolk and 58% white. The yolk contains about 50% solids of which one third is protein and two third lipids. Egg white is essentially an aqueous solution containing about 12% protein.

Proteins of Marine Origin

Fish flesh contains on an average 10-21% protein. Fish muscle proteins, like those of mammalian muscle are generally classified as sarcoplasmic, myofibrillar and stroma proteins but their proportions differ.

Proteins of Plant Origin

The protein source of vegetarian diet is from cereals, pulses and oil seeds besides small quantities from vegetables.

Cereals like wheat and rice are important sources of protein because they are the staple foods of Indians. On an average wheat has 12-13% protein while rice has 7-9% protein. Gluten proteins are responsible for the unique bread making property of wheat. Wheat and rice proteins are generally deficient in the essential amino acid lysine.

Seed Proteins

Legumes (pulses) and oil seeds are major sources of vegetable proteins. The average protein content of the major pulses is given in Table 4.1.

Table 4.1: Protein content of major pulses

Legume	Protein (%)
Bengal gram dhal	20.8
Black gram dhal	24.6
Field bean, dry	24.9
Green gram dhal	24.5
Lentil (lens culinaris Medic)	25.1
Peas, dried	19.7

The average protein content of some of the oil seeds is given in Table 4.2.

Table 4.2: Protein content of some oil seeds

Oilseed	Protein (%)
Ground nut	26.7
Soybean	43.2
Sesame	18.3
Cotton seed	19.5
Sunflower seed	12.5

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain protein denaturation.

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2. What are the major difference between proteins of animals and plants?

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3. Name four good sources of plant proteins.

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4 Which are essential amino acids?

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4.3 ENZYMES

Enzymes are called bio- catalysts. They are globular protein catalysts that accelerate several biological reactions. Enzymes are present in all biological systems both plant and animal. Enzymes show high degree of specificity. This property is very important in food processing where it is often desirable to modify only a single component in the process.

4.3.1 Nomenclature and Classification

Enzymes are classified into six major groups depending on the type of reactions they catalyze i.e. 1) oxido reductases, 2) transferases, 3) hydrolases, 4) lyases, 5) isomerases and 6) ligases

Over the years, thousands of enzymes have been isolated and identified. Quite often two or three enzymes differ only slightly from one another in their properties causing difficulty in naming them. Therefore, the International Union of Biochemistry on Nomenclature and Classification of Enzymes has assigned a code number of four numerals for each enzyme, which fully identifies an enzyme. However it is too cumbersome to follow this classification and therefore for routine purpose most of the enzymes have been given a trivial name, which is short and simple.

4.3.2 Properties of Enzymes

As already mentioned, all enzymes are proteins but all proteins are not enzymes. Some enzymes consist of protein only, but most enzymes contain additional non- protein components such as carbohydrates, lipids, metals, phosphates or some other organic moiety. The complete enzyme is called holoenzyme, the protein part apoenzyme and the non- protein part cofactor. The compound which is being converted in an enzyme reaction is called substrate, In an enzyme reaction the substrate combines with the holoenzyme and is released in a modified form as shown below.

$$\text{Enzyme} + \text{Substrate} \leftrightarrows \text{Complex} \leftrightarrows \text{Enzyme} + \text{Products}$$

Enzyme activity is affected by various factors like temperature, pH, chemicals etc. By far the most important is the requirement of optimum temperature and pH for their maximum activity. These properties serve both for obtaining maximum activity for an enzyme as well as for inhibiting the enzyme activity.

By far the largest group of enzymes important in food processing is the hydrolases. A few oxido reductases and isomerases are also encountered. Hydrolases catalyse the following general reaction.

$$AB + HOH \rightarrow HA + BOH$$

Typical examples of hydrolases are amylases, pectin esterase, poly galacturonase, proteases, lipases etc. Most of the enzymes used in industrial applications are now obtained from microorganisms. Table 4.3 gives examples of some of the important enzymes encountered in food processing.

Table 4.3: Some enzymes used in food processing

Enzyme	Food	Purpose/ action
Amylases	Baked products Brewing	Increase sugar content for yeast fermentation Conversion of starch to maltose for fermentation
Invertase	Artificial honey	Conversion of sucrose to glucose and fructose
Naringinase	Citrus juice	De-bittering of citrus juice
Pectinases	Fruit juice	Improve yield and clarity
Proteases	Brewing Meat and fish	Clarification, chill-proofing Tenderization
Lipases	Oils	Hydrolytic rancidity (deteriorative)
Glucose oxidase	Egg powder	Prevention of browning by removing glucose
Polyphenol oxidase	Fruits	Enzymatic browning (deteriorative)

4.3.3 Immobilized Enzymes

One of the most important recent developments in the use of enzymes in industrial food processing is the fixing of enzymes on water insoluble inert supports. The fixed enzymes retain their activity and can be easily added or removed from the reaction mixture. The use of immobilized enzymes permits continuous processing and repeated use of the enzyme. Another important use of immobilized enzymes is in analytical and medical fields.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the role of enzymes?

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2. Are all proteins enzymes?

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3. Explain immobilized enzymes?

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4.4 WATER

Water is an essential constituent of most foods. It may occur as an inter cellular and/or extra cellular component in vegetables and animal products, as a dispersing medium or solvent in a variety of products, as the dispersed phase in some emulsified products such as butter or margarine and as a minor constituent in other cases. The presence of water influences deterioration of food, either chemical or microbiological. Thus an understanding of its properties and its behaviour in foods is of great importance.

4.4.1 State of Water in Foods

Water is present in foods in different forms. They are grossly characterised as bound water and free water. Bound water is the water, which is bound to other constituents of foods like proteins and remains unfrozen. This water is unavailable as a solvent. The state of water in food is described by the relationship between the moisture content of the product and the relative humidity of the air surrounding it. This ratio is called water activity, which is an important characteristic of the system. The relative humidity corresponding to each specific moisture content of the product called equilibrium relative humidity (ERH) and the following relationship applies.

$$a_w = p/p_o = ERH/100$$

where a_w = water activity
p = partial pressure of water in food
p_o = vapour pressure of water at the same temperature
ERH = Equilibrium Relative Humidity in %

At high moisture contents, when the amount of moisture exceeds that of solids, the activity of water is close to or equal to 1.0. When the moisture content is lower than this amount, water activity is lower than 1.0. Below moisture content of about 50% the water activity decreases rapidly and the relationship between water content and relative humidity is represented by the sorption isotherm. The adsorption and desorption processes are not fully reversible;

therefore, a distinction can be made between the adsorption and desorption isotherms according to whether a dry product is subjected to increasing moisture levels or whether the moist product is gradually equilibrated with lower moisture levels and the product is being dried. Figure 4.3 shows the adsorption desorption isotherms.

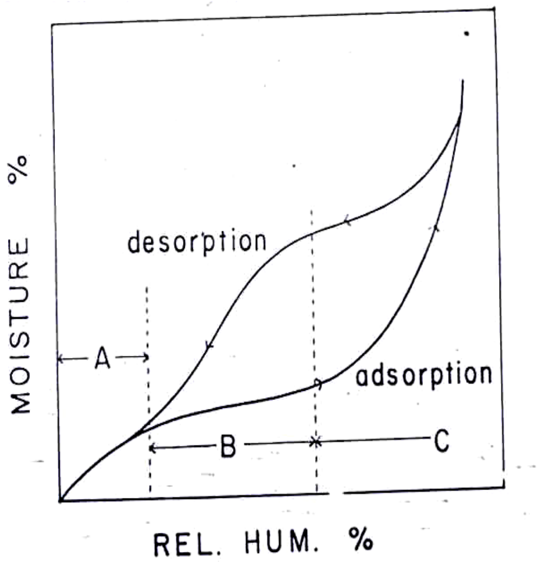

Figure 4.3: Adsorption desorption isotherms

Generally the isotherms are required for the observation of hygroscopic products and the desorption isotherms are useful for investigation of the process of drying. A steeply sloping curve indicates that the material is hygroscopic and a flat curve points to a product, which is not sensitive to moisture.

4.4.2 Water Activity and Food Spoilage

Moisture content and water activity are of major importance in affecting a progress of chemical and microbiological spoilage reactions in foods. Dried and dehydrated foods have very good microbiological stability though browning reactions take place. Such products have moisture content in the range of 5-15% and have low water activity. Intermediate moisture foods (IMF) have moisture content in the range of 20–40% and are fairly shelf stable. IMFs generally have water activity above 0.5. Adding/having soluble solids like sugar achieve this. Example of such products is jams, preserves, cakes, dry fruits, etc. Bacterial growth is practically nil below water activity of 0.90. Yeasts and moulds are usually inhibited between 0.88 and 0.80 water activity, although some osmophilic yeast can tolerate water activity as low as 0.65.

Most enzyme reactions are inhibited below water activity of 0.85. Non-enzymatic browning reactions are dependent on water activity showing maximum around 0.6–0.7. Since water activity is a major factor influencing the keeping quality of a number of foods, it is obvious that packaging can play an important role to maintain optimal conditions for long storage life. Packaging aspects will be dealt with in another section.

4.4.3 Freezing of Water

During freezing of water, the water molecules arrange themselves in a tetrahedral fashion. These results in a hexagonal crystal lattice which is loosely built and has relatively large hallow spaces resulting in high specific volume. This is the reason for increase in volume of water on freezing. You must have observed ice cubes floating on water. The density of ice at 0° C is only 0.9168.

Water can exist in three phases, viz., solid, liquid and gas. The conditions under which they exist are separated by three equilibrium lines (Figure 4.4).

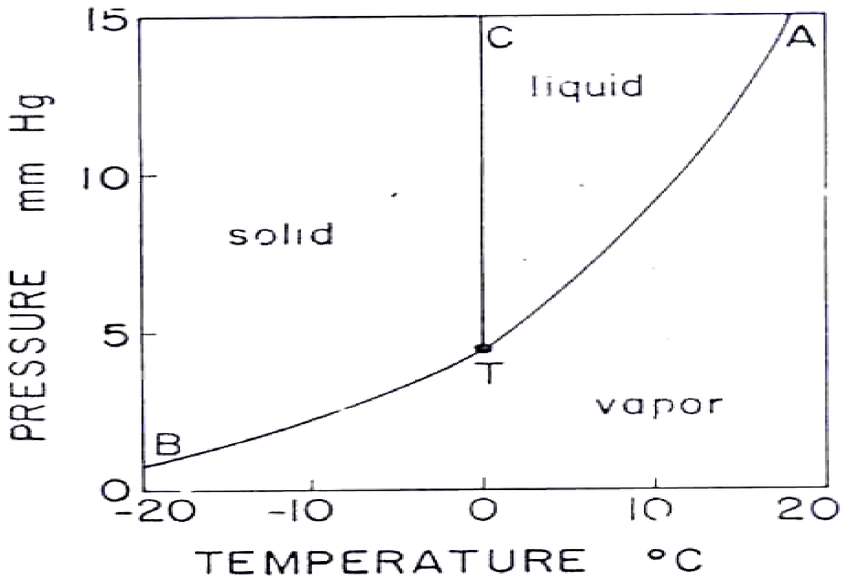

Figure 4.4: Phase diagram of water

The vapour pressure line TA, the melting pressure line TC and sublimation pressure line BT. They meet at the triple point T, where all three phases are in equilibrium. When ice is heated at pressures below 4.58 mm Hg it changes directly into vapour form (sublimation). This is the basis of freeze-drying.

Slow freezing will result in large ice crystal formation and rapid freezing in tiny ice crystal formation. Large ice crystals tend to damage the cell walls resulting in texture lose in frozen fruits, fish, meat, etc. During freezing of foods, water is transformed to ice with high degree of purity and solid concentration in the unfrozen liquid is gradually increased. This is accompanied by changes in pH, ionic strength, viscosity, osmotic pressure, vapour pressure and other properties. These changes along with the lower temperature are responsible for decrease in microbial activity and often on destruction of micro- organisms in frozen foods.

4.4.4 Water Quality and Standards

Water is used for different purposes in food processing. They include water used as ingredient in finished products, for generating steam, for cleaning raw materials, for cleaning plant and equipment, as heat exchange medium for heating and cooling etc. The water quality for different purposes varies.

In general, only potable water should be used in the preparation of food indented for human consumption. Potable water is that water which contains no bacteria capable of causing human intestinal diseases and is aesthetically satisfactory for drinking purposes, i.e. free from undesirable odours and flavours.

Potable water should have good clarity, colourless and free from objectionable odour and taste.

Hardness of Water

Calcium and magnesium salts cause hardness of water. Permanent hardness is due to chlorides and sulphates of calcium and magnesium and temporary hardness is due to bicarbonates of these ions. Hardness is expressed as ppm (parts per million i.e. mg per litre) of $CaCO_3$ (calcium carbonate) on which basis water is classified according to degree of hardness (Table 4.4).

Table 4.4: Classification of water based on hardness

ppm of $CaCO_3$	Condition
Less than 50	Soft
50 to 100	Slightly hard
100 to 200	Hard
Above 200	Very hard

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the relationship between water activity and food spoilage.

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2. Why quick freezing better than slow freezing?

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3. Explain hardness of water.

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Microbiological Quality

The bacteriological quality of water used throughout the plant should meet the standards required for drinking water. The fitness of water for drinking purposes with respect to bacterial content is determined by the presence or absence of the coliform group of bacteria including Escherichia and Aerobacter species which indicate the possibility of faecal contamination. Waters drawn from deep wells or those purified by artificial means seldom show the presence of E.coli in 100 ml.

The quality of water required varies for different process food industries. The essential microbiological parameters of the BIS standards for water meant for general purposes are given in Table 4.5.

Table 4.5: Bacteriological tolerances

Sl. No.	Characteristic	Tolerance
1.	Coliform bacteria, MPN index/100 ml.	Less than 1
2.	Standard plate count, per ml., Max.	50 (Note 1)
3.	Proteolytic and lipolytic organisms, combined count per ml. Max.	5 (Note 2)

4.4.5 Chlorination

As in the case of municipal water supply, chlorination of industrial water has become a common practice in food processing plants as a means of improving plant sanitation. Gaseous chlorine or calcium and sodium hypochlorites are used for chlorination of water.

Chlorine Demand of Water

When chlorine is added to water other than distilled water, a small amount, normally 0.25 to 0.75 ppm, reacts with impurities in the water. This quantity of chlorine is called the **chlorine demand** of the water. The impurities responsible for chlorine demand include compounds containing iron, manganese, nitrites and sulphides. The chlorine, which reacts with these compounds, has no germicidal properties and cannot be measured by the methods used for testing chlorine concentration.

Break Point Chlorination

When chlorine is added to water, initially it is used up to satisfy the chlorine demand of the water. As additional chlorine is added, a free residual chlorine appears. At the same time, some chlorine loosely combines with nitrogenous matter present in water to form chloro-nitrogen compounds. The residual chlorine gradually increases until it reaches a concentration depending on the physical and chemical nature of the water, at which an oxidation reaction occurs between the free chlorine and the chloro-nitrogen compounds. The free residual nitrogen is decreased by the amount necessary to completely oxidise the chloro-nitrogen compounds. Further addition of chlorine beyond this point will result in a second rise in free chlorine concentration, which increases in almost direct proportion to the rate of chlorine application (Figure 4.5). The point after the first rise in concentration at which the free residual chlorine reaches its lowest level is known as the break point. Break point chlorination is defined as chlorination to a degree where a persisting residual chlorine of 2-10 ppm occurs. The residual chlorine in water exists either as free chlorine or chlorine which has loosely combined with other elements. The rate at which bacteria exposed to chlorine are killed is proportional to the amount of chlorine present as hypochlorous acid.

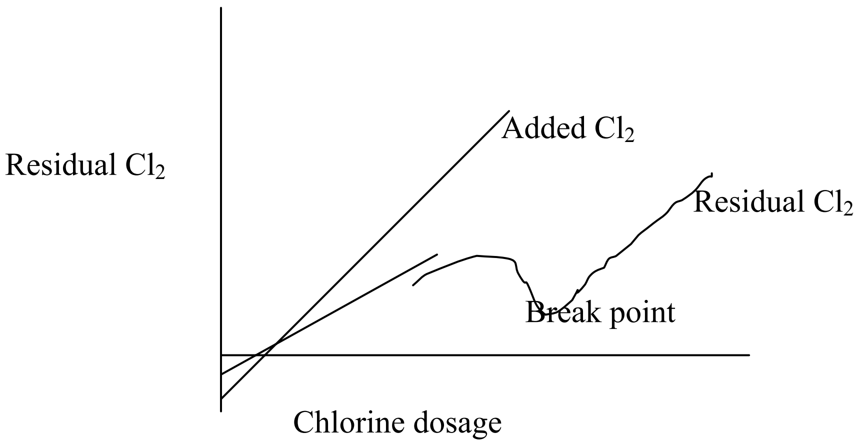

Figure 4.5: Break point chlorination of water

Chlorination of Water

In plant chlorination reduces bacterial count and clean up time and avoids odours. Chlorination of cooling water (for cooling canned products) prevents spoilage from recontamination. Residual chlorine of 5 ppm in the water is considered sufficient. Residual chlorine of 10-20 ppm is recommended for cleaning purposes. Chlorine concentration of 5 ppm has no effect on the flavour, odour or colour of canned products. For chlorination of water, hypochlorites are usually added in the form of stock solution containing 5000–10000 ppm of chlorine.

4.4.6 Packaged Drinking Water

As all of us know the quality of water supplied for drinking in many parts of our country is very poor and varies from place to place. Several diseases are spread through water. That is why today we find a booming packaged drinking water industry in the country. Water meant for producing packaged drinking water goes through a series of treatment and processes like filtration, reverse osmosis, ozonisation, etc., to obtain the required quality. PFA has laid down detailed specifications for packaged drinking water. The salient aspects of the specification are given in Table 4.6.

Table 4.6: Specifications for packaged drinking water

Sl. No.	Characteristics	Requirements
1.	Total soluble solids	Not more than 500 mg/litre
2.	PH	6.5–8.5
3.	Nitrates (as NO3)	Not more than 45 mg/litre
4.	Nitrites (as NO2)	Not more than 0.02 mg/litre
5.	Sulphide (as H2S)	Not more than 0.05 mg/litre
6.	Manganese (as Mn)	Not more than 0.1 mg/litre
7.	Copper (as Cu)	Not more than 0.05 mg/litre
8.	Zinc (as Zn)	Not more than 5.0 mg/litre
9.	Fluoride (as F)	Not more than 1.0 mg/litre
10.	Barium (as Ba)	Not more than 1.0 mg/litre
11.	Nickel (as Ni)	Not more than 0.02 mg/litre
12.	Chlorides (as Cl)	Not more than 200 mg/litre
13.	Sulphate (as SO4)	Not more than 200 mg/litre
14.	Calcium (as Ca)	Not more than 75 mg/litre
15.	Sodium (as Na)	Not more than 200 mg/litre
16.	Arsenic (as As)	Not more than 0.05 mg/litre
17.	Cadmium (as Cd)	Not more than 0.01 mg/litre
18.	Chromium (as Cr)	Not more than 0.05 mg/litre
19.	Mercury (as Hg)	Not more than 0.001 mg/litre
20.	Lead (as Pb)	Not more than 0.01 mg/litre
21.	Iron (as Fe)	Not more than 0.1 mg/litre
22.	Residual free chlorine	Not more than 0.2 mg/litre
23.	Yeast and mould counts	Absent in 250 ml
24.	E.Coli	Absent in 250 ml
25.	Coliform Bacteria	Absent in 250 ml
26.	Faecal streptococci and staphylococcus aureus	Absent in 250 ml
27.	Aerobic microbial count	Shall not exceed 100/ml.

4.4.7 Water Analysis

In the examination of water supplies, the test will depend on the purpose for which the water is used. The initial examination of water, or the testing of supplies from a new source may consist of the following:

I. Sanitary Examination

1. Physical characteristics:

   i) Colour, ii) Odour and taste, iii) Turbidity

2. Chemical characteristics:

   i) Total solids,
   ii) Organic matter,
   iii) Hardness,
   iv) Alkalinity,
   v) Acidity,

vi) pH,
vii) Nitrogen as nitrates, nitrites, free ammonia and albuminoid ammonia,
viii) Chlorides,
ix) Sulphates,
x) Free CO_2,
xi) Oxygen absorption, and
xii) Heavy metals.

II. Microbiological Examination

1. Plate count
2. Coliform count
3. Faecal streptococci test
4. Clostridium welchii test.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which are the microorganisms or concern in potable water?

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2. Define chlorine demand and break point in chlorination.

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3. Which are the components of water analysis?

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4.5 LET US SUM UP

Proteins are macromolecules built up of amino acids. They form the building block of animal and human body structure. Pulses, oil seeds, and animal and marine foods are good sources of protein. The quality of protein greatly depends on its essential amino acid makeup.

Enzymes are biocatalysts, which catalyse biological reactions. All enzymes are proteins but all proteins are not enzymes. Several enzymes find application in food processing.

Water is an essential component of foods. Its state in foods plays an important role in food preservation. Quality of water used in food processing operations and for drinking is of paramount importance. Water is treated in several ways to make it suitable for different purposes.

4.6 KEY WORDS

Amino acids : Nitrogen containing compounds having both carboxyl and amino groups.

Essential amino acids : Amino acids which cannot be synthesised by the human body.

Albumin : Proteins, which are soluble in neutral salt free water.

Denaturation : Change in the structure of protein without breaking covalent bonds.

Immobilised enzymes : Enzymes fixed on water insoluble inert supports.

Chlorine demand : The quantity of chlorine added which reacts with the impurities in water and which does not show up as free chlorine.

4.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Aliphatic, aromatic, etc.
2. Different classes of simple proteins
3. Conjugated proteins

Check Your Progress Exercise 2

Your answer should include the following points:

1. Coagulation of egg albumin.
2. Deficiency of amino acids like lysine.
3. Pulses, oil seeds.
4. Valine, lysine, methionene, etc.

Check Your Progress Exercise 3

Your answer should include the following points:

1. Bio catalyst.
2. All enzymes are proteins.
3. Enzymes fixed on inert support.

Check Your Progress Exercise 4

Your answer should include the following points:

1. Relationship of water activity to microbial growth.
2. Large ice crystals damage cell structures.
3. Calcium and magnesium salts.

Check Your Progress Exercise 5

Your answer should include the following points:

1. Coliforms.
2. Reaction of added chlorine with impurities in water.
3. Depression in residual chlorine content.
4. Physical, chemical, microbiological.

4.8 SOME USEFUL BOOKS

1. Owen R. Fennema, (1976) Principles of food science, Part I- Food Chemistry, Marcel Decker Inc.; New York.

2. Meyer, L.H. (1969) Food Chemistry, Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.

3. Braverman, J.B.S. (1963) Introduction to the Biochemistry of foods, Elsevier Publishing Company, Amsterdam, London, New York.

4. Ranganna, S. (2000) Hand book of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

UNIT 5 FOOD CONSTITUENTS – VITAMINS AND MINERALS

Structure

5.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the chemistry and properties of different vitamins;
- their physiological functions and deficiency diseases;
- their dietary sources; and
- describe the importance of minerals in human nutrition.

5.1 INTRODUCTION

You have already learnt about the macronutrients viz. carbohydrate, protein and fat. Besides these macronutrients, the human body requires certain accessory factors called vitamins for maintaining the health and well being. The accessory factors were named vitamins because of their vital importance to health. Some of the vitamins are unstable to the adverse storage conditions of foods and also many processing conditions. Since the vitamins are present in foods only in minute concentrations, their protection during preservation and processing of foods is a major concern.

The human body requires several minerals also for maintaining normal health. Iron and iodine deficiencies among populations are well known. Due to various reasons, the foods consumed by sections of the populations are deficient in vitamins and minerals. Therefore, these are some times added to foods. Since vitamins and minerals are collectively termed 'micronutrients', the process of adding them to foods is called micronutrient fortification. You will be learning these aspects in this unit.

5.2 VITAMINS

Vitamins are organic substances of very diverse composition required by the body usually in very minute quantities. Some of them, especially the B-group vitamins, take an active part in enzymatic reactions as co-enzymes. You will be learning more on enzymes in another unit. Most of the vitamins are supplied to the body by plants. Vitamins do not supply energy to the body or any structural units for bodybuilding. They, however, play a most important role in the energy transfer as well as in control of many metabolic processes. Some of the vitamins like vitamin A occur in plant foods as provitamins (e.g. β-carotene), compounds that are not vitamins but can be transformed by the body into vitamins.

Vitamins are generally classified into two groups: a) fat-soluble vitamins i.e., vitamins soluble in fats and fat-soluble solvents (like petroleum ether, chloroform, carbon tetrachloride etc.) but not soluble in water, and b) water soluble vitamins, i.e., vitamins soluble in water but insoluble in fats or fat-soluble solvents.

5.2.1 Fat Soluble Vitamins

Fat soluble vitamins include 1) Vitamin A and Carotene (Provitamins A), 2) Vitamin D, 3) Vitamin E and 4) Vitamin K.

Vitamin A (Retinol)

Osborne and Mendel (1913) and McCollum and Davis (1917) showed that a fat-soluble factor present in butter was essential for the growth of rats on synthetic diet. The latter workers called the factor as "fat-soluble A". Moore (1930) showed that when large amounts of carotene are fed to vitamin A deficient rats, vitamin A was found in large amounts in liver, indicating the conversion of carotene to vitamin A in the animal body.

Chemistry and properties: In 1931, Karrer determined the structure of vitamin A. In 1937, Kuhn and Morris announced a method of synthesis if vitamin.

Vitamin A contains a β-ionone ring and a highly unsaturated side chain. Due to the unsaturated side chain, vitamin A is destroyed easily by oxidation. Being an alcohol, it forms esters such as acetate, succinate, palmitate etc. Vitamin A is stable to heat (100^{o}C) for short periods in the absence of oxygen. Vitamin A is slowly destroyed when exposed to light.

A large number of carotenoid pigments occur in nature. You will be learning their structure and properties in a later section in this unit. Carotenes are converted into vitamin A in the body. Among the carotenes, β-carotene has maximum vitamin A activity.

Functions and deficiency diseases/syndromes: Vitamin A has various functions in the human body. It is essential for the maintenance of normal vision, building and growth of skeletal cells and provides resistance power to the body. Dietary retinoids, especially carotenoid compounds have been found to suppress carcinogenesis (development of cancer).

The most important effect of deficiency of this vitamin in the diet is night blindness. In early stages of vitamin A deficiency, one cannot see well in dim light. In advanced deficiency, the subject cannot see objects in dim light. Night blindness is very common in regions where vitamin A intake is inadequate.

Dietary sources: Vitamin A is present only in fish liver oil and foods of animal origin such as liver, eggs, milk and fatty fish. Plant foods contain only carotenoids, the precursor of vitamin A. Among the plant foods, green leafy vegetables, carrot, mango and other yellow coloured fruits are good sources of carotenes.

Vitamin A levels are frequently expressed in International Units (I.U.). One I.U. equals 0.3 μg of crystalline vitamin A alcohol (retinol) or 0.6 μg β-carotene.

Vitamin D

Mellanby (1919) discovered that cod liver oil can cure or prevent experimentally produced rickets in dogs. McCollum and co-workers (1922) established experimentally that the antirachitic vitamin was different from vitamin A and called the factor vitamin D.

Chemistry and properties: Vitamin D is a group of compounds related to sterols. This vitamin occurs in several forms, the two most important are vitamin D_2 or ergocalciferol and vitamin D_3 or cholecalciferol.

Vitamin D is fairly heat stable. It is unstable on exposure to ultra-violet light. It is soluble in fat solvents.

Functions and deficiency diseases/syndromes: Vitamin D is essential for bone formation. It promotes absorption of calcium and phosphorus and deposition in bones.

In vitamin D deficiency, calcification (calcium deposition) of bone does not take place. This results in the disease called rickets in infants and children. The manifestations of the disease are: bowleg, enlargement of ankles and wrists and deformities of the chest bones called 'pigeon breast'. Exposure of children suffering from rickets to sunlight has a curative effect. Therefore, vitamin D is also called the sunshine vitamin.

Dietary sources: Vitamin D_2 occurs in small amounts in fish liver oils. Vitamin D_3 is widely distributed in eggs, milk, butter and cheese but large amounts occur only in fish liver oils.

One international unit (I.U.) of vitamin D is equivalent to the activity of 0.025 μg of pure crystalline vitamin D_2.

Vitamin E

Evans and Bishop (1922) discovered that for normal reproduction in rats, a fat-soluble factor present in crude vegetable oils was essential. They termed it vitamin E. Evans and co-workers (1936) isolated two compounds α and β-tocopherols possessing vitamin E activity.

Chemistry and properties: Tocopherols are derivatives of 6-hydroxy chroman with a phytyl side chain. Tocopherols are soluble in fat solvents and insoluble in water. Tocopherols have excellent antioxidant properties. The storage stability of unrefined vegetable oils is due to the tocopherols. They are slowly destroyed in alkaline medium and the vitamin activity is destroyed by oxidation.

Functions and deficiency diseases/syndromes: Vitamin E is essential for normal reproduction in several species of animals and also in man. Its deficiency causes several disorders such as reproductive failure, liver necrosis (damage), muscular dystrophy, etc.

Dietary sources: Cereal germ oils like wheat germ oil and corn germ oils are the richest natural sources of the vitamin. Soybean oil is also a good source of tocopherols. Cottonseed oil is found to contain alpha, beta, and gamma tocopherols. Delta tocopherols were isolated from soybean oil. Since alpha tocopherols have the highest biological activity, its content is taken for calculating the human requirements.

One international unit (I.U.) of vitamin E is equal to the activity of 1 mg of synthetic α- tocopherols.

Vitamin K

As early as 1934, Dam and Schonheyder found that chicks fed on purified diets containing all vitamins known at that time developed haemorrhagic condition, which was cured by Lucerne (alfalfa) leaves. They named it vitamin K (Koagulations-vitamin) meaning vitamin responsible for blood coagulation.

Chemistry and properties: Vitamin K belongs to the group of compounds called quinones. Vitamin K_1 is called phylloquinone and K_2 is called menaquinone. Vitamin K_1 is 2-methyl 3-phytyl- 1,4-napthoquinone. It is the only vitamin K found in plants.

The commercially available vitaminK_1 is prepared synthetically from isophytol and a derivative of menadione. Vitamin K is also a fat-soluble vitamin.

Functions and deficiency diseases/syndromes: Vitamin K is essential for blood clotting by increasing the prothrombin levels in blood. Vitamin K deficiency leads to increased blood clotting time. This may lead to haemorrhage conditions. The deficiency can occur either due to inadequate intake or inadequate intestinal absorption of vitamin K. Inadequate intestinal absorption can occur due to disease of the liver or diarrhoea.

Dietary sources: Vitamin K occurs widely in plant foods, especially in leafy vegetables and also synthesised by the intestinal micro flora. It is assumed that almost 50% of the vitamin requirement is derived from intestinal micro organisms. Animal foods contain little vitamin K.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the difference between fat-soluble and water soluble vitamins? Name four fat-soluble vitamins.

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2. Which vitamin is required for normal vision? Why beta-carotene is called pro-vitamins A? List a few foods rich in beta-carotene.

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3. What is the chemical nature of vitamin K? List the physiological functions of the vitamin.

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4. Which vitamin is required for normal reproduction? List a few foods rich in the vitamin.

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5.2.2 Water Soluble Vitamins

Water soluble vitamins are classified into two groups viz.1) vitamins of the B group to which most of the water soluble vitamins belong and 2) vitamin C.

Vitamin B_1 (Thiamine)

Vitamin B_1 was the first of the B-vitamins discovered. A Dutch doctor, Eijkman, demonstrated in 1897 that a very common disease, beriberi, which prevailed at that time in the Dutch East Indians, was caused through feeding only polished rice. Jansen and Donath (1926) isolated vitamin B_1 in crystalline form from rice polishings. This vitamin is also called thiamine.

Chemistry and properties: Williams and co-workers established the chemical structure of thiamine in 1936. Thiamine contains a pyrimidine ring and thiazole ring. It is a white crystalline powder. Sulphur dioxide destroys the vitamin activity of thiamine. Therefore, sulphites shoud not be added as a preservative to foods rich in thiamine. Thiamine is stable to heat in acid foods but it is less stable in neutral foods. It is destroyed by alkali. During wet processing, thiamine is leached out. Baking of cereal products shows considerable loss in thiamine content.

Functions and deficiency diseases/syndromes: Thiamine functions in carbohydrate metabolism. Free thiamine is readily absorbable by small intestine. It is necessary for nerve function, appetite and normal digestion.

Mild deficiency of the vitamin leads to loss of appetite, fatigue, depression and irritability. Severe deficiency causes a disease called Beriberi. There are three types of beriberi occurring in human beings viz. wet, dry and infantile beriberi.

Wet beriberi produces three general symptoms: a) Polyneuritis (inflammation of nerves), b) Oedema (swelling), and c) Disturbances of the heart. Muscle soreness and loss of reflex of the knee take place. The body tissues swell and oedema develops and it is noticed in the legs and thigh of the patient. Breathing becomes difficult and the heart becomes weak. Death occurs due to heart failure.

Dry beriberi affects the nerves of legs and arms. Calf muscles become tender and swollen. Toes and ankles get numb. The emaciated subject needs the help of sticks to stand and walk and finally becomes bedridden.

Infantile beriberi affects infants below 6 months. Two types of infentile beriberi are known. They are a) cardiovascular type, and 2) neuritic type.

Dietary sources: Whole cereals, pulses (legumes), oilseeds and nuts are good sources of thiamine.

Vitamin B_2 (Riboflavin)

In 1926, Goldberger and co-workers showed that pellagra was cured by autoclaved yeast, which was devoid of thiamine. This factor was called vitamon B_2. However, later studies showed that the vitamin so defined was a complex of several vitamins and riboflavin was one of them. Riboflavin does not cure pellagra.

Chemistry and properties: Riboflavin has a cyclic iso alloxazine nucleus and has a side chain containing a pentose sugar (ribose).

Riboflavin is slightly soluble in water and ethyl alcohol. The solution when exposed to ultra-violet light emits a strong greenish yellow fluorescence. Riboflavin is stable in acid or neutral medium but is destroyed in alkaline medium especially on heating.

Functions and deficiency diseases/syndromes: Riboflavin is concerned in the regulatory function of insulin. The retina contains riboflavin, which is converted by light to a compound involved in stimulation of the optic nerve. It forms a part of enzyme systems involved in the metabolism of carbohydrates, fats and proteins. Flavin Adenine Dinucleotide (FAD) and Flavin Mono Nucleotide (FMN) are formed from riboflavin.

Deficiency of riboflavin in the diet causes oral and facial, scrotal, vulval, and also ocular lesions.

Dietary sources: Liver, dried yeast, egg powder, whole and skim milk powder are excellent sources of riboflavin. Milk, cheese, eggs, whole grain and green leafy vegetables are also good sources.

Niacin (Nicotinic Acid)

The discovery of niacin was also associated with yeast extract as in the case of thiamine and riboflavin. It was isolated from liver and found that it can cure 'pellagra' in man and 'black tongue' in dogs. Niacin (nicotinic acid) is also called vitamin B_3.

Chemistry and properties: Acid or alkaline solutions of nicotinic acid on heating is converted to nicotinamide. It is one of the most stable of the vitamins. It is stable to acids, bases, oxidizing agents, heat and light. However, it is destroyed by autoclaving at 120^0C for 20 minutes. It is sparingly soluble in cold water, but soluble in hot water and alcohol. Nicotinamide exists almost exclusively as a constituent of coenzymes NAD (nicotinamide adenine dinucleotide and NADP (nicotinamide adenine dinucleotide phosphate).

Functions and deficiency diseases/syndromes: Nicotinic acid is essential for the normal functioning if the skin, intestinal tract and the nervous system. Deficiency of Niacin leads to a disease known as pellagra. In pellagra disease dermatitis, glossitis and stomatitis occur. Dermatitis is appears wherever that part of the body is exposed to sunlight. The other symptoms are irritability, mental anxiety and depression, which can develop to delirium and dementia.

Dietary sources: Yeast, liver, meat, poultry, wholegrains, fresh pork are excellent sources of niacin. Good proteins like milk protein are associated with niacin because triptophan, an amino acid, present in the proteins is converted into niacin in the body. It has been estimated that 60 mg of triptophan yield 1 mg of niacin.

Vitamin B_6 (Pyridoxin)

Pyridoxine is one of the vitamins of the B group, which prevents dermatitis. It was isolated in 1938 in pure form by different groups of workers. Pyridoxine is also called vitamin B_6.

Chemistry and properties: Pyridoxine does not belong to only one class of compound. It consists of three related substances namely pyridoxine, pyridoxal and pyridoxamine.

Pyridoxine contains a pyridine nucleus, two primary alcoholic groups and one phenolic hydroxyl group. Pyridoxal contains an aldehyde group in place of one primary alcoholic group and pyridoxal amine contains a primary amine side chain in place of a primary alcohol group. Pyridoxine is readily soluble in water and alcohol. It slowly gets destroyed when exposed to sunlight. Neutral or alkaline solutions of pyridoxine are heat labile. Oxidising substances like potassium permanganate and hydrogen peroxide also destroy it.

Functions and deficiency diseases/syndromes: Pyridoxine is essential for growth of infants. Its deficiency produces degeneration of the nerves. It has also some influence on the functioning of hormones. Besides pyridoxine play important roles in amino acid and lipid metabolism. Pyridoxal phosphate acts as a coenzyme for a number of enzyme systems. It removes carbon dioxide from the acid groups of certain amino acids and transfer amine groups from one compound to another. Pyridotal phosphate helps in transamination reactions, poryphyrin synthesis etc.

Dietary sources: Pyridoxine is widely distributed in both plant and animal foods. Dried yeast, rice polishing, wheat germ and liver are excellent sources. Whole cereals, legumes, oil seeds, nuts, egg, milk, meat and fish and leafy vegetables are good sources of this vitamin.

Pantothenic Acid

Pantothenic acid is one of the B group vitamins. In 1933, Williams reported that a factor present in yeast could prevent a specific type of pellagra (chick pellagra). This factor was named pantothenic acid.

Chemistry and properties: Pantothenic acid is an unstable, viscous oil. It is soluble in water. It contains an amino acid namely alanine. It is stable to heat but destroyed by acid and alkali. It is readily absorbed from small intestines.

Functions and deficiency diseases/syndromes: Pantothenic acid has an important role in the metabolism of Co-enzyme A. Therefore, indirectly pantothenic acid has a role in the utilization of carbohydrates and fats. Deficiency diseases of the vitamin are not often observed in man. However some of the deficiency disease symptoms are headache, fatigue, weakness, sleeplessness, nausea etc.

Dietary sources: It is widely distributed in foods. Dried yeasts, liver, rice polishing, wheat germs, fleshy foods, eggs, fish etc. are good sources of pantothenic acid.

Biotin

In 1916, Bateman showed that when rats were fed with uncooked egg white, they developed the peculiar skin disease. This condition was called egg-white injury. This was due to a toxic component called avidin. Gyorgi in 1931 isolated an anti-egg white injury factor from yeasts and named it as vitamin H. Later this factor was found in egg yolk and it was called Biotin.

Chemistry and properties: Biotin is sparingly soluble in cold water and freely soluble in hot water. It is stable to heat but sensitive to acid, alkali and oxidizing agents. It forms salts with alkali hydroxides.

Functions and deficiency diseases/syndromes: Biotin is essential for the activity of many enzyme systems. It helps in maintaining the skin structure and is necessary for normal gestation and lactation in animals. It is also required for fatty acid metabolism.

Biotin deficiency does not occur in humans frequently. Experimental deficiency in animals has shown skin scaling, dermatitis, muscle pains, anorexia (lack of appetite) and slight anaemia.

Dietary sources: Biotin occurs widely in foods of both vegetable and animal origin. Peanuts, chocolates, egg yolk, liver, kidney, peas, cauliflower, dry yeast, milk products, cereals etc. are good sources. Royal jelly from honeybee is the richest source of biotin (400 μg / 100 g).

Folic Acid

Wills (1934) showed that a vitamin present in autolysed yeast extract cured tropical macrocytic anaemia in humans. Mitchell, Snell and Williams (1941) reported the presence of this factor in spinach leaves essential for the growth of L-casei (a micro organism). They called this factor folic acid (*folium* meaning leaf).

Chemistry and properties: Folic acid is also called pteroyl glutamic acid. It is widely distributed in nature. It is a yellow crystalline compound moderately soluble in hot water and stable to heat. Many bacteria produce this vitamin.

Functions and deficiency diseases/syndromes: It is essential for the maturation of Red Blood Cells (RBC). It acts as co-enzyme in the transfer of single carbon groups such as methyl or formyl. It is essential for reproduction in animals. It also helps in the hair growth and health of skin.

Folic acid deficiency causes megaloblastic anaemia, which is also called macrocytic anaemia. This mainly occurs in pregnant women. This is due to accumulation of immature RBCs in bone marrow. Inadequate supply of folic acid causes glossitis (red sore tongue), diarrhoea, and anaemia.

Dietary sources: Dried yeast, green leafy vegetables, dry beans, cabbage, soybean, yeast, kidney and liver are good sources of this vitamin.

Vitamin B_{12}

In 1926, Minot and Murphy found that feeding liver in large quantities could control pernicious anaemia. In 1929, Castle also found that beef muscle is effective in controlling pernicious anaemia. Both these factors were responsible due to Vitamin B_{12}. It is also called Cyanocobalamin.

Chemistry and properties: Cyanocobalamin has a complicated chemical structure. It contains a porphyrin nucleus and a molecule of cobalt (4-5%).

Vitamin B_{12} is a water-soluble dark red crystalline compound not stable to acids and alkali. When it is exposed to sunlight it gets partially destroyed.

Functions and deficiency diseases/syndromes: Vitamin B_{12} promotes the maturation of Red Blood Cells (RBC). It is essential for the normal function of bone marrow and the nervous system. B_{12} takes part in many enzymatic reactions. It is essential for the absorption of Calcium and Phosphorus. It aids in providing energy to the central nervous system. It also helps in the increase of white blood cells and blood platelet count.

Deficiency of the vitamin causes pernicious anaemia. Life span of RBCs also comes down. The shape and size of RBCs also change. The other symptoms are skin lesions, reduction in gastric secretion, effect on spinal cord, tingling, numbness, loss of sense of limbs, depression etc.

Dietary sources: Vitamin B_{12} is present only in foods of animal origin. Kidney and liver, egg, cheese, milk, fish etc. are good sources of the vitamin.

Vitamin C (Ascorbic Acid)

Man knew the disease scurvy since centuries. It was found that sailors on long voyage were suffering from this disease. This was due to the non-availability of fresh fruits and vegetables to sailors in their long journey. Szent-Gyorgy (1928) isolated an acid with intense reducing properties from cabbage, orange and adrenal glands. Subsequently it was named ascorbic acid due to its antiscorbutic properties.

Chemistry and properties: Haworth and co-workers established the chemical structure of ascorbic acid in 1933. It is a six carbon mono basic acid present in its lactonised form. Its reducing property is due to the presence of a di-enolic configuration.Vitamin-C is a white water soluble crystalline compound stable in acid solution but sensitive to oxidation. Ascorbic acid has strong reducing property. It loses two hydrogen and forms dehydroascorbic acid. It is sensitive to high temperature. Vitamin-C is lost during food processing, storage and cooking.

Functions and deficiency diseases/syndromes: Vitamin C is essential for the formation of collagen and osteoblasts, for carbohydrate and cholesterol metabolism, for oxidation of phenylalanine to tyrosine, for the absorption of iron, and for rapid healing of wounds. Severe deficiency of the vitamin results in the development of the disease called scurvy. The disease is characterised by general weakness, spongy bleeding gums, loose tooth swollen joints and haemorrhages in various tissues.

Dietary sources: Ascorbic acid is widely distributed in the plant kingdom. Many fruits and vegetables like amla, orange, lemon, guava, cabbage, etc. are good sources of the vitamin.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is beriberi?

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2. What is the chemical nature of niacin? Which disease is caused by its deficiency?

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3. What are the roles of vitamin B_{12} in the human system? List a few dietary sources of the vitamin.

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4. What is the chemical nature of ascorbic acid? Why it has reducing property? List a few foods rich in ascorbic acid.

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5.3 MINERALS

Proteins, carbohydrates and fats belong to organic compounds whereas minerals are inorganic in nature. When a food material is completely burnt, we are left with ash. This ash is nothing but minerals. These minerals are very essential to our body and they are included under the category called micronutrients.

The body contains about 24 minerals, all of which must be supplied by the diet. These minerals are necessary for the following different functions: 1) as constituents of bones and teeth e.g. Calcium, phosphorus and magnesium; 2) as constituents of body cells of soft tissues like muscles, liver etc. e.g. Phosphorous; 3) as soluble salts which give to the body fluids and cell contents, their composition and stability which are both essential for life, e.g., sodium, potassium, chloride, and phosphorous; 4) some minerals are required in small quantities for specific functions, e.g., iron and copper for formation of hemoglobin; iodine for formation of thyroxine; zinc a constituent of a co-enzyme; cobalt the constituent of vitamin B_{12} and some other elements are essential for the activity of various enzymes. Minerals are classified into macro-minerals and micro minerals. Macro minerals are required in higher quantities and micro minerals are required in much smaller quantities. Calcium, phosphorous, magnesium, sodium and potassium are generally classified as macro minerals while iron, iodine, fluorine, manganese, cobalt, selenium, cobalt etc are classified under micro minerals. The physiological functions and dietary sources of some minerals are given in the following table.

Physiological functions of some minerals

Sl. No.	Mineral	Functions	Sources
1.	Calcium	Essential for the formation of bones and teeth. Absorption of Vitamin B12 and contraction of heart and muscles.	Milk and milk products, green leafy vegetables, ragi, egg and fish, etc.
2.	Phosphorus	Essential for formation and growth of bones and teeth, metabolism and transport of lipids and maintenance of acid base balance.	Rice and wheat bran, cheese, milk, meat and fruits and vegetables, etc.
3.	Sodium	Essential for acid base balance, regulation of osmotic pressure in cell fluids, maintenance of blood pressure and regulation of heart beat.	Table salt, milk meat, shell fish, egg, cheese, leafy vegetables, etc.
4.	Potassium	Essential for acid base balance, conduction of nerve impulses, conversion of glucose to glycogen and growth and build-up for tissues.	Fruits, dry fruits, milk, beans, etc.
5.	Magnesium	Takes part in the activity of more than 300 enzymes, vital for the functions of nerves, bones and muscles and teeth, role in coagulation of blood.	Green vegetables. Nuts, cereals, milk, etc.
6.	Iron	Component of haemoglobin, transport and storage of oxygen, essential for cell respiration.	Cereals, sea foods, meat, egg, vegetables, etc.

7.	Iodine	Normal thyroid function, deficiency causes goiter, i.e. Swelling of the thyroid gland and decrease of thyroidal hormone production.	Drinking water, Iodized salt, marine foods, meat, milk, fruits and vegetables, cereals, etc.
8.	Fluorine	Essential for bone and teeth formation, prevents tooth decay. Deficiency causes dental caries. Excess chlorine causes dental fluorosis.	Drinking water, milk, sea foods, garlic, tea, etc.
9.	Manganese	Takes part in the activity of many enzymes, helps in the development of bones, role in the regulation of fats and carbohydrates	Cereals, pulses , oil seeds, milk, vegetables, etc.
10.	Copper	Helps in the absorption and utilization of iron, influence on the oxygen supply, formation of melanin and phospholipids, takes part in enzyme activity.	Seeds, nuts, mushrooms, etc.
11.	Zinc	Aids in carbohydrate and protein metabolism, role in production of insulin, takes part in enzyme activity.	Cheese, fish, meat, egg, oyster, cereals, etc.
12.	Chromium	Influence on carbohydrate metabolism, stabilization of blood sugar level, influence on appetite.	Poultry, meat, milk, potato, nuts, etc.
13.	Selenium	Component of various enzymes, acts as an antioxidant, has protective effect against cancer.	Soybean, meat, fish, etc.
14.	Cobalt	Component of vitamin B12, Role in carbohydrate and lipid metabolism, role in synthesis of proteins.	Animal foods especially liver

Micronutrient Fortification

As compared to the major nutrients viz. carbohydrate, protein and fat, the other essential nutrients like the vitamins and minerals are required by the human system only in minute quantities. Therefore, they are termed as 'micronutrients'. Due to lack of access to balanced foods, certain sections of the population suffers from severe micronutrient deficiency. To improve the quality of the diet, these nutrients are some times added to foods. This process is called 'micronutrient fortification'. For example, iodine is added to table salt to prevent goiter and iron is added to wheat flour to prevent anemia. Vitamin fortified foods are also not rare. During fortification, the following precautions have to be taken.

1. Only the required concentration of the nutrient should be added to foods.
2. Fortification should not affect the stability of the food product.
3. It should not affect the colour and taste of the end product.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which minerals are required for the formation of bones and teeth? List a few dietary sources for the minerals.

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2. Which diseases are caused by the deficiency of iodine and fluorine?

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3. Enumerate the importance of iron and cobalt in human nutrition.

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5.4 LET US SUM UP

Vitamins are complex organic substances required by the human body for several vital and well-defined physiological functions. They are mostly derived from plant sources. Because there is no structural relationship among the different vitamins, their classification is practically not possible. However, based on their solubility characteristics they are classified into fat soluble (soluble in fat and fat solvents) and water soluble vitamins. Most of the water-soluble vitamins belong to the group of the B complex. Many of the B complex vitamins take part in various enzymatic reactions as coenzymes.

The human body also requires several minerals for its physiological functions. Many of the minerals are cofactors of enzyme systems. Deficiency of some minerals cause specific diseases like for example, deficiency of iodine causes 'goitre' and deficiency of fluorine causes 'dental caries'.

Since all the vitamins and minerals are not present in sufficient quantities in the staple diets of sections of the population, their deficiencies are common. In order to alleviate the deficiency, some foods are fortified with these nutrients.

5.5 KEY WORDS

Vitamin	:	Of vital importance
Retinol	:	Vitamin A alcohol
Provitamin A	:	Carotenes, which are converted to vitamin A in the body.
Liver necrosis	:	Liver damage due to disease.
Prothrombin	:	Substance in blood responsible for normal blood clotting.
Beriberi	:	The disease caused by the deficiency of vitamin B_1.
FAD	:	Flavin adenine dinucleotide.
FMN	:	Flavin mono nucleotide.
Pellagra	:	The disease caused by the deficiency of niacin.
Scurvy	:	The disease caused by deficiency of vitamin C.
Goitre	:	The disease caused by deficiency of iodine.
Dental caries	:	The disease caused by deficiency of fluorine.
Micro nutrients	:	Vitamins and minerals.

5.6 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Solubility in fat and fat-soluble solvents and water.
   - Vitamin A, D, E and K

2. Your answer should include the following points:

   - Vitamin A.
   - Beta carotene gets converted to vitamin A in the human body.
   - Green leafy vegetables, yellow fruits and vegetables like mango, papaya, carrot.

3. Your answer should include the following points:

   - Quinone
   - Blood clotting

4. Your answer should include the following points:

   - Vitamin E
   - Cereal germ oils, soybean oil, cottonseed oil

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Deficiency of vitamin B_1

2. Your answer should include the following points:

   - Nicotinic acid, nicotinamide
   - Pellagra

3. Your answer should include the following points:

   - RBC
   - Pernicious anaemia
   - Absorption of Ca, P
   - Animal foods eg. liver

4. Your answer should include the following points:

   - Six carbon monobasic acid
   - Di-enol
   - Citrus fruits, amla, guava

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Ca, P
   - Milk, ragi, leafy vegetables, rice and wheat bran, fish

2. Your answer should include the following points:

   - Goitre
   - Dental caries

3. Your answer should include the following points:

   - Haemoglobin
   - Anaemia
   - Oxygen transport
   - Vitamin B_{12}
   - Carbohydrate and lipid metabolism

5.7 SOME USEFUL BOOKS

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3. Owen, R. Fennema, (1976) Principles of food science, Part I- Food Chemistry, Marcel Decker Inc.; New York.

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UNIT 6 FOOD ADDITIVES

Structure

6.0 OBJECTIVES

After reading this unit, you should be able to answer:

- the definition of food additives;
- different types of food additives;
- their chemical properties and functions in foods; and
- their legal status for the purpose of adding to foods.

6.1 INTRODUCTION

Food additives have been used for centuries to enhance the quality of food products. Smoke, alcohol, vinegar, and spices were used more than 10,000 years ago to preserve foods. Along with the developments in Food Chemistry and Food preservation in the early 1900s, the use of food additives increased significantly. The demand for new, tasty, convenient, and nutritious foods continued to increase. As a result, by the early 1960s, over 2500 different chemicals were being used in foods in many developed countries.

Different people used to understand food additive in different ways. The widely accepted definition of food additive is:

> "a substance or mixture of substances, other than a basic foodstuff, which is present in a food as a result of any aspect of production, processing, storage, or packaging. The term does not include chance contaminants".

Food additives are substances intentionally added for specific functions. The number of additives being used in food today is very large. However, they can be classified into a few types based on their functional properties. They may include: 1) preservatives, 2) antioxidants, 3) acidulants, neutralizers and buffers, 4) colouring agents, 5) flavouring agents, 6) sweeteners 7) nutritional additives, and 8) miscellaneous additives.

The use of food additives is well-accepted practice but not without controversy. There have been a number of concerns regarding the potential short-term and long-term risks of consuming these substances. Based on the available scientific information on the toxicological status of each additive and the likely quantity of that additive consumed through a particular food, the maximum permissible limits (Acceptable Daily Intake, ADI) of additives have been stipulated. As you will be learning in subsequent units, each country has laid down its own food legislation and The Prevention of Food Adulteration Act (PFA) and Rules, 1954, in India lists the additives permitted in different foods and their maximum permissible limits. You will also be learning that our food standards are in the process of harmonisation with international food standards. Therefore, it is likely that the present list of permitted additives under PFA may increase in the near future. Keeping these points in mind, in this unit some important and versatile food additives are included even though some of them may not be permitted under PFA at present. The nutritional additives viz. vitamins and minerals have already been dealt with in the previous unit; they will not be included in this unit.

6.2 PRESERVATIVES

From prehistoric times humans have attempted to preserve food products from the deteriorative effects of microorganisms. Some chemical food preservatives like salt, nitrites and sulphites have been in use for many years. Even though newer packaging techniques, processing and storage methods are able to preserve foods without chemical preservatives, even today these chemicals play a significant role in protecting the food supply mainly because preservation using chemical preservatives is cheaper and more convenient.

Under PFA, 1954, preservatives are classified into Class I and Class II preservatives. Class I preservatives are also called natural preservatives. They are, common salt, sugar, dextrose (glucose), spices, vinegar or acetic acid, honey, and vegetable oils. There is no restriction to the addition of Class I preservatives to any food.

Class II preservatives are, Benzoic acid and its salts, sulphurous acids and its salts, nitrates or nitrites, sorbic acid and its sodium, potassium and calcium salts, calcium or sodium propionates, lactic acid, sodium or calcium propionate, methyl or propyl parahydroxy benzoic acid, sodium diacetate and sodium potassium and calcium lactate.

Among the above preservatives, benzoates and sulphites are most widely used for preservation of fruit and vegetable products. Sorbates have been permitted for some products lately. Therefore, these and a few natural preservatives will be dealt with in this unit.

6.2.1 Class I Preservatives

1) *Salt (sodium chloride):* Salt has been used as a preservative since the beginning of recorded history. Pickling of fruits and vegetables and salting of fish and meat are widely practiced. The anti- microbial activity of sodium chloride is essentially related to its ability to reduce water activity (a_w) and create unfavourable conditions for microbial growth. As the water activity of the external medium is reduced, microbial cells are subjected to osmotic shock and rapidly lose water through plasmolysis. These results in the cells ceasing to grow and either die or remain dormant. Aside from the osmotic influence on microbial growth, other possible mechanisms include limiting oxygen solubility in the medium and toxicity of chloride ions.

   Sodium chloride-intolerant bacteria are inhibited by concentrations as low as 1%. Some bacteria like the lactic acid bacteria used in producing lactic fermented vegetables (you have learned in the units under 'Food fermentations') can tolerate from 6–15 % sodium chloride. In general, food borne pathogenic bacteria are inhibited by a water activity of 0.92 or less which is equivalent to sodium chloride concentration of 13%. That is why for salt curing, sodium chloride concentration of about 13% is commonly used.

   The inhibitory effect of sodium chloride is dependent on several factors particularly pH. As acidity increases, less sodium chloride is required to inhibit microbial growth.

2) *Acetic acid:* Synthetic vinegar (dilute acetic acid) and brewed vinegar are widely used as acidulants and antimicrobials. Vinegar pickles are common in our country.

   Acetic acid is more effective against yeasts and bacteria than moulds. Only acetic, lactic and butyric bacteria are markedly tolerant to acetic acid. As is the case with most other preservatives, acetic acid is also more effective at lower pH. Generally, 1-2 % acetic acid is sufficient to inhibit most of the organisms.

3) *Sugar and spices:* They also have preservative effects in many food products. The main function of sugar is to reduce the water activity of the medium thus inhibiting the growth of microorganisms. Many chemical substances in spices (terpenes) have been shown to have antimicrobial properties.

6.2.2 Class II Preservatives

As mentioned above, there are a number of chemicals having preservative action. However, only a few of them are permitted for use in foods. So, what are the factors to be considered in selecting a preservative for a food?

How to select a preservative?

Firstly the effectiveness of the preservative against different types of spoilage organisms must be known. This along with the knowledge of the common spoilage organisms associated with the product will allow the selection of the correct preservative for the product. Secondly, the physico-chemical properties of both the preservative and the product should be known. The ionisation and solubility characteristics of the preservative in the product as well as the pH of the product are important factors. Finally, the safety and legality of the preservative chosen must be known.

Benzoic acid and benzoates: Benzoic acid is found naturally in cranberries, plums, prunes, cinnamon, cloves and most berries. It is a strong antimycotic agent. Most yeasts and moulds can be controlled using 0.05–0.1% benzoic acid. Control of many bacteria requires much higher concentration. Benzoic acid is sparingly soluble in water (0.27% at 18^{o}C). As sodium benzoate has higher solubility (66% at 15^{o}C), it is mostly used for preservation. Benzoates are most effective at low pH (pH 2.5–4.0) because the undissociated form is the effective antimicrobial agent.

Benzoic acid is permitted in several products like squashes, syrups, crushes, fruit juices, jams, jellies, marmalade, beverages, pickles and tomato products. You will be learning its maximum permissible limits in these products in the course on different products. Benzoic acid and its sodium and potassium salts have been generally recognised as safe (GRAS).

Sulphur dioxide and sulphites: Sulphur dioxide and its various salts have a long history of use dating back to the times of the ancient Greeks. They have been used extensively as antimicrobials and to prevent enzymatic and nonenzymatic browning in a variety of food products.

Sulphur dioxide is a colourless, non-flammable gas with a suffocating odour. It dissolves readily in water to produce sulphurous acid (H_2SO_3). Sulphur dioxide and its salts (bisulphites and metabisulphites) exist in a pH – dependent equilibrium in solution.

As the pH decreases, the proportion of the undissociated H_2SO_3 increases. As in the case of benzoic acid, the undissociated sulphurous acid has more antimicrobial activity than the dissociated ions.

Sulphurous acid inhibits yeasts, moulds and bacteria. However, yeasts and moulds are less sensitive than bacteria. That is the reason why sulphur dioxide is used at low concentrations (about 100 ppm) during grape juice fermentation to control the growth of other microorganisms and facilitate growth of yeast. Sulphur dioxide and sulphites are permitted under PFA for a number of products like fruit pulps, squashes, syrups, crushes, cordials, wines, RTS beverages, and dehydrated fruits and vegetables. Sulphur dioxide is also used as an antibrowning agent. Fruits are exposed to fumes of burning sulphur before drying to prevent browning and also insect and microbial attack. Sulphite solutions are also used as dip solution for vegetables before drying or dehydration.

Sulphur dioxide and several sulphites have GRAS status. However, sulphites cannot be used in meats and in foods that are sources of the vitamin thiamine. As sulphites have strong bleaching action on plant pigments like anthocyanins, they should not be used for preserving such products. It has been found that sulphites show allergic responses in certain individuals, such as steroiddependent asthmatics. This has led to ban of use of sulphites on raw fruits and vegetables in many countries.

Sorbic acid and sorbates: Sorbic acid and its sodium, potassium and calcium salts are collectively known as sorbates. Sorbic acid is present in some berries like berries of the mountain ash berry (rowanberry). It is a trans-trans, unsaturated monocarboxylic fatty acid.

The acid is a white crystalline powder and is slightly soluble in water (0.16% at 20°C). The potassium salt, which is highly soluble in water (58.2% at 20°C), is mostly used as the preservative. However for preservation of oils like corn oil, the acid is used because the salt is practically insoluble.

In the case of sorbic acid also, the undissociated acid has the highest antimicrobial activity. Therefore, sorbic acid is also more effective at low pH. However the dissociated acid also shows microbial action, though of a lower order. At pH above 6, the dissociated acid is responsible for more than 50% of the inhibition observed. This is the reason why sorbates are preferred for products like chapatti and cheese.

Sorbates inhibit most of the species of yeasts and moulds. Several species of bacteria are also inhibited by sorbates. At present under PFA, sorbates are permitted for only a few fruit and vegetable products. They include jams, jellies, marmalades, glazed or candied fruits, fruit bars, fruit juice concentrates and prunes. Some of the other products include cheese, flour confectionary, smoked fish, preserved chapatties and fat spreads. Sorbic acid and potassium sorbate have GRAS status.

Nitrites: Nitrites have been used in meat curing for many centuries. For meat curing, nitrite is used along with a mixture of salt, sugar, spices, and ascorbate. Nitrite contributes to the development of the characteristic colour, flavour, and texture improvement and preservative effects.

Nitrites are white or pale yellow hygroscopic crystals. Sodium nitrite is quite soluble in water. Nitrite has a strong inhibitory action against *Clostridium botulinum* and several other microorganisms. It is more effective below neutral pH (below 7.0). Along with salt, nitrite exhibits stronger antimicrobial action.

Biologically derived antimicrobials

Antimicrobial substances (antibiotics) produced by microorganisms have been known for many years. However, some of these substances are allowed for food use only in recent years. Nisin, and natamycin have been permitted in some foods.

Nisin is a polypeptide produced by *Steptrococcus lactis* (now called *lactococcus lactis*). The solubility of the compound depends on the pH of the medium. It is more soluble in acidic pH and almost insoluble in neutral pH.

Nisin has a narrow spectrum affecting only gram-positive bacteria, including lactic acid bacteria, streptococci, bacilli, and clostridia. It generally does not inhibit gram-negative bacteria, yeasts or moulds. The antimicrobial action of nisin is pH dependent, increases as the pH decreases. It is effective at very low concentrations of the order of 0.04–2.0 ppm. Nisin has been permitted in packaged coconut water and canned rasagolla under PFA.

Natamycin: It is produced by the bacterium *Streptomyces natalensis*. The compound has a large lactone ring which is substituted with one or more sugar residues. Natamycin is primarily effective against yeast and moulds and is ineffective against bacteria, viruses and actinomyces. Natamycin is also effective at very low concentrations of the order of 5-10 ppm. Natamycin has been permitted for surface treatment of hard cheese.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define food additive.

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2. How are preservatives classified under PFA? List the Class I preservatives.

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3. List the permitted (PFA) Class II preservatives. What are the functions of sulphites in foods?

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6.3 ANTIOXIDANTS

Antioxidants play important role in preserving fats, oils and fatty foods. You have already learnt the chemistry of oils and fats. They are essentially fatty acid esters of glycerine. The fatty acids can be either saturated or unsaturated. The unsaturated fatty acids in fats and oils can undergo oxidation during storage leading to rancidity development. Along with rancidity development, vitamin destruction, discolouration and even toxic effects are possible.

Lipid oxidation is often referred to as an autocatalytic reaction. It is a complex reaction, which once initiated will become a chain reaction. Food antioxidants are substances that are able to inhibit or interfere with the autoxidation reaction fundamental to glyceride oxidation. In simple terms, they get oxidised in preference to the fats and oils.

You have already learnt that tocopherols present in many vegetable oils have antioxidant property. Similarly, ascorbic acid and lecithin have antioxidant properties. However, the major antioxidants commercially used in foods, fats and oils are phenolic compounds and are generally referred to as phenolic antioxidants. Certain metals like iron and copper present in foods are strong catalysts of fat oxidation and may react with antioxidants to cause discolouration. Food acids like citric acid have the ability to bind these metals. Therefore, the antioxidants are usually added along with citric acid.

The most widely used phenolic antioxidants for fats and oils are i) butylated hydroxy anisole (BHA), ii) butylated hydroxy toluene (BHT), iii) propyl gallate and iv) tert-butyl hydroquinone (TBHQ).

Butylated hydroxy anisole (BHA): BHA is a white, waxy solid that is usually tableted to minimize caking during storage. It is readily soluble in glycerides and organic solvents and insoluble in water and has a distinct phenolic odour. BHA is quite stable during normal processing and storage of fatty foods. Therefore, it is considered to have good carry-through effect. However, being volatile at high temperatures, BHA may be lost partially during deep fat frying.

Butylated hydroxy toluene (BHT): BHT is a white, crystalline solid. It is also soluble in glycerides, and insoluble in water. It has a fair degree of carry-through effect but partially lost by volatilisation at high temperatures. BHT is less effective as an antioxidant than BHA.

Propyl gallate: Propyl gallate is the n-propyl ester of 3,4,5- trihydroxy benzoic acid or gallic acid. It is a white to light grey powder. It has low oil solubility and significant water solubility. Though it has very good antioxidative properties, due to its heat-labile nature; it has very little carry-through properties especially under alkaline conditions encountered in baked foods. Therefore, propyl gallate is used in combination with other antioxidants like BHA thus providing the combined effects of improved storage stability and carry-through protection.

tert-Butyl hydroquinone (TBHQ): TBHQ is a white to light tan crystalline solid noted for its effectiveness in increasing the storage stability of fats and oils. It is moderately soluble in fats and oils, and only slightly soluble in water. Unlike the other phenolic antioxidants, it does not form coloured compounds with metal ions in foods like iron, which is an advantage. TBHQ provides good carry-through protection to fried foods.

Applications of phenolic antioxidants

As mentioned earlier, among the food additives, perhaps the antioxidants are the most widely used. They are used in vegetable oils, meat products, confections and chewing gums, cereal products like breakfast cereals, bakery products etc. Use of the antioxidants in fruit and vegetable products though limited, is of considerable commercial importance. Some of them include fruit nuts like walnut, almonds, cashew nuts; citrus oils, dehydrated potato products like powder, flakes and granules.

Under PFA, all the above phenolic antioxidants **except BHT** have been permitted with restrictions. Additionally, lecithin and ascorbil palmitate are also permitted for specific food products.

6.4 ACIDULANTS

Acidulants contribute a variety of functional properties that lead to the enhancement of food quality. Most of the acidulants used in food are organic acids. The organic acids and their salts commonly used in foods are acetic, ascorbic, citric, lactic, malic and tartaric acids. Inorganic acids like phosphoric acid is also used extensively in cola type beverages. Organic acids like citric, malic and tartaric acids are widely distributed in pants. Ascorbic acid, which is vitamin C, is also of plant origin. Lactic acid as the name implies is derived from milk. Since some aspects of acetic and ascorbic acids were already covered elsewhere, they are not specifically discussed here.

Citric acid is perhaps the most widely used organic acid. It is a tricarboxylic acid abundantly present in citrus and many other fruits. Even though it used to be produced from citrus fruits, at present most of the commercial citric acid is manufactured by fermentation. Citric acid is a white crystalline powder, easily soluble in water. Commercial citric acid is available as the monohydrate. It is hygroscopic in nature. Therefore, citric acid is not very suitable for use in dry food formulations.

Malic acid is 2-hydroxybutanoic acid, which is a dicarboxylic acid. It is the major acid in apples and mango. It is a crystalline white powder, easily soluble in water. Synthetic malic acid is available commercially. Since it is not hygroscopic, malic acid is preferred for use in dry food formulations.

Tartaric acid is also a dicarboxylic acid. It is the predominant acid in grapes and tamarind. It is also a white crystalline solid, soluble in water. It is usually extracted from the argol sediment formed during fermentation of grapes. Tartaric acid finds application in baking powder and effervescent 'health salts'.

General functions of acidulants

The proper selection of an acid is dependent on which property or combination of properties of the acid is desired as well as its cost. Some of the general functions are given below.

- *Flavouring agents:* They intensify certain tastes and flavours, mask undesirable tastes
- *Buffering action:* The salts of organic acids, especially the sodium salts control the pH of food during various stages of processing as well as of the finished products.
- *Preservation:* By reducing pH, prevent growth of microorganisms and the germination of spores, which lead to spoilage and food poisoning.

- *Sequestering:* Bind metal ions and enhance the function of antioxidants.
- *Viscosity modifiers:* Like in dough, consequently modifying the shape and texture of baked foods.
- *Meat curing agent:* Together with other curing components, enhance colour, flavour and preservative action.

Most of the food acidulants are permitted under PFA with certain restrictions.

6.5 COLOURING AGENTS

Food colouring agents (colourants) may often be considered simply of cosmetic in nature, but the role they play is actually very important. You will be learning more about this quality attribute of food in a subsequent unit.

The addition of colourants to foods in order to make them more attractive is not a new invention. Extracts of spices and vegetables were used for the purpose as early as 1500 B.C. The advent of the use of food colourants in the late 1800s and early 1900s was unfortunately accompanied by their misuse in food adulteration, frequently to disguise food of poor quality. Some of these deceptive practices included colouring of pickles with copper sulphate; cheese with vermillion and red lead; tea with copper arsenite, lead chromate and indigo; and candy and turmeric with lead chromate, red and white lead and vermillion.

Development of synthetic dyes became a boon to the food industry because these colourants were superior to natural extracts in tinctorial strength (colour intensity), number of shades, stability, and easy availability and was cheap. However, safety is the most important aspect of synthetic food colours. Extensive toxicological studies have been carried out on these colourants in different countries. While many of the colourants have been found to be harmful, a few others appeared to be safe for use depending on various factors like the quantity of the colourant consumed. Besides, the test methods followed in different countries varied, which have resulted in much scientific and political debate. Consequently, colourants considered safe in one country may not be considered safe in another country. The toxicological studies are revealing newer information and hence the regulatory status of the colourants used in countries throughout the world is in a state of flux. One common observation is that the number of permitted synthetic colourants is decreasing year by year.

The regulatory status of several natural colourants is less severe mainly because they are mostly extracted from edible plant sources. Another class of colourants are called **nature-identical** colourants. They are those identical counterparts of naturally occurring pigments. Some examples of nature-identical colourants are β -carotene, canthaxanthine, and β -apo-8'-carotenal. Their regulatory status is similar to natural colourants.

Under PFA, the following natural and synthetic colours are permitted at present with restrictions on their maximum levels and the specific food products.

Natural colouring matters

1. Beta carotene
2. Beta – apo -8’-carotenal
3. Methyl ester of beta – apo - 8’- carotenoic acid
4. Ethyl ester of beta – apo - 8’- carotenoic acid
5. Canthaxanthin
6. Chlorophyll
7. Riboflavin (lactoflavin)
8. Caramel
9. Annato
10. Saffron
11. Curcumin (or turmeric)

Synthetic food colours

Sl.No.	Common Name	Shade	Chemical class
1.	Ponceau 4R	Red	Azo
2.	Carmoisine	Red	Azo
3.	Erythrosine	Red	Xanthene
4.	Tartrazine	Yellow	Pyrazolone
5.	Sunset yellow FCF	Yellow	Azo
6.	Indigo carmine	Blue	Indigoid
7.	Brilliant blue FCF	Blue	Triaryl methane
8.	Fast green FCF	Green	Triaryl methane

6.5.1 Natural Food Colourants

Anthocyanins: Anthocyanins are the intense red and blue water-soluble pigments occurring in many fruits, vegetables and flowers like strawberries, cranberries, raspberries, blueberries, grapes (blue), Jamun, and some flowers. Anthocyanins are composed of an aglicone (anthocyanidin) esterified to one or more sugars and may be acylated. The sugars may be glucose, rhamnose, galctose, xylose and arbinose. Grape skin and elderberries are good commercial sources of anthocyanin pigments.

The anthocyanin double ring benzopyran structure is very reactive. The compounds are easily ionised and tend to become colourless above pH 4.5. They exibit their most intense colours below pH 3.5. Therefore, these colourants are only suited for acidic foods. Anthocyanins easily undergo discolouration in the presence of amino acids, phenolic sugar derivatives etc. They are also bleached by ascorbic acid and sulphites.

Carotenoids: Carotenoids are responsible for the yellow, orange and red pigments in a number of plants and animal foods. Carotenoids are classified into three groups. i) Carotenes – These are hydrocarbons containing β-ionone rings and possess vitamin-A activity. Ex. β-Carotene present in carrots, chillies, soybean. ii) Lycopenes – These are carotenoids not having β-ionone rings and do not possess vitamin-A activity. Lycopene is present in tomato, apricot, watermelon, and red guavas. iii) Xantohphylls – These are oxygenated derivatives of carotene. These have β-ionone rings, but do not possess vitamin-

A activity. They are present in papaya, orange peel, and yellow maize. iv) α-Carotene – This is similar to β-carotene in its biological activity.

Chemically carotenoids are poly –enes composed of isoprene units. They are fat soluble and fairly heat stable. During processing of fruits and vegetables, partial loss of carotene takes place. They are stable at pH 2–7. As a result of their chemical structure, which contains conjugated double bonds, carotenoids are very sensitive to oxidation. Ascorbic acid can protect β -carotene by serving as an antioxidant. "Nature-identical" synthetic β -carotene is marketed in forms that confer protection from oxidation.

Betalains: Betalains are found in plants such as red beets, amaranthus flowers, bougainvillea, cactus fruits etc. Betalain colours range from red to yellow. The red beet is the most common commercial source of these pigments. Betalains are sensitive to pH, light and heat. These compounds are most stable at pH 4 – 5. Because of the carbohydrates present in betalains, the colourants tend to impart beet flavour to the food.

Production of colourants like anthocyanins and betalains by tissue culture technique offers the advantage of a more reliable supply of the colours independent of plant variability and elimination of the strong undesirable plant flavours.

Chlorophylls: Chlorophylls, the most abundant naturally occurring plant pigments, are the green and olive green pigments in green plants. Chlorophylls are obtained from a wide variety of sources and they are mixture of 2 compounds namely chlorophyll a and chlorophyll b present in the ratio of 3a: 1b in plants. They belong to a group of important biological pigments called porphyrins, which include haemoglobin, and is composed of four pyrole rings held together. Magnesium is located in the centre of the molecule.

Chlorophylls are soluble in alcohol, diethyl ether, benzene, acetone etc. but insoluble in water. Some metal ions like iron, zinc and copper react with chlorophyll and the green colour becomes brighter. In alkaline pH, the colour of chlorophyll is better retained. Chlorophylls are heat sensitive and during processing of fruits and vegetables containing chlorophyll, the green colour is lost and turns brown. When vegetables containing chlorophyll is cooked, the central Mg atom is replaced by hydrogen atom and loses it's colour forming pheophytin. Chlorophylls may be stabilized by replacement of the magnesium ion in the compound with copper.

Curcumin is the main colourant (yellow) in the oleoresin obtained from turmeric (*Curcuma longa*). Curcumin is fat-soluble, has good tinctoriasl strength, but exhibit slight sensitivity to light, air and pH.

Paprika oleoresin, which is orange red to deep red, is the extract of mild capsicum (*Capcicum annum*). Like curcumin, paprica oleoresin is also water insoluble. Paprika and turmeric oleoresins are available in various standardized forms.

Saffron is generally stable toward light, oxidation and pH and has a high tinctorial strength.

6.5.2 Synthetic Colourants

Synthetic colourants, also known as coal tar dyes or aniline dyes were earlier manufactured from coal tar derivatives. Although the colourants were highly purified before they were added to foods, the negative connotation of their association with coal tar resulted in much unfavourable publicity. As a result, synthetic colourants are no longer manufactured from coal tar derivatives but instead are developed from highly purified petrochemicals.

As can be seen from the table above, the permitted synthetic colorants belong to five chemical classes viz. azo, xanthene, pyrazole, indigoid and triarylmethane. You may notice that all together there are three red, two yellow, two blue and one green colour permitted under PFA. All these colours are water-soluble. As mentioned earlier, these colours are more resistant to chemical reaction, pH and heat compared to natural colourants.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the function of an antioxidant in foods?

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2. List two natural and three phenolic antioxidants.

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3. Describe the general functions of acidulants in foods?

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4. List the synthetic colours permitted in foods under PFA.

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6.6 FLAVOURING AGENTS

Flavour like colour of foods has a great bearing on acceptance of foods and therefore, has enormous commercial importance. It apparently has no nutritional value although some studies have indicated that taste can alter intestinal absorption of glucose and fat metabolism. Flavour is defined in several ways. One definition is: "**sensation produced by a material taken in the mouth, perceived principally by the senses of taste and smell, and also by general pain, tactile and temperature receptors in the mouth".**

Food flavours is a very vast subject. You will be learning sensory perception and analysis of flavour in a subsequent unit. In this section you will learn some essential aspects of the chemistry and application of food flavourings.

During the early days, people used spices to enhance or modify the flavour of foods. Along with the developments in synthetic chemistry and analytical techniques like gas chromatography and mass spectrometry, there was a spurt in synthetic flavour compounds and identification of the flavour compounds in various foods and processed products. The role of sensory analytical techniques in flavour research is very significant. One major finding was that most of the food flavours were due to a combination of a number of chemical compounds and only in a few cases, one single compound was responsible for the characteristic flavour of a food. Few examples are menthol in peppermint, benzaldehyde in bitter almond, citral in lime peel, amyl acetate in ripe banana, cinnamaldehyde in cinnamon etc. Therefore, it became apparent that creation of a food flavour is not an easy task. However, with a combination of art and scientific know-how, today a large number of flavour formulations are available. It is an extremely large industry. Food flavourings are classified into three groups.

1. *Natural flavours and natural flavouring substances:* They are flavour preparations and single substances respectively acceptable for human consumption, obtained exclusively by physical means from vegetable, sometimes animal raw materials, either in their natural state or processed, for human consumption.

2. *Nature-identical flavouring substances:* They are substances chemically isolated from aromatic raw materials or obtained synthetically, they are chemically identical to substances present in natural products intented for human consumption, either processed or not.

3. *Artificial flavouring substances:* They are those substances, which have not been identified, in natural products intended for human consumption either processed or not.

The natural flavours include spice oleoresins and oils, essential oils like citrus oils; fruit aroma concentrates like apple aroma concentrate etc. As indicated earlier, the number of synthetic flavour substances is extremely large. Therefore, instead of listing the permitted flavouring substances, only those, which are not permitted, are specified under PFA. In this connection it is important to note that the concentrations of the flavour chemicals in natural or synthetic flavours to impart the desired flavour perception are extremely low, of the order of parts per million or parts per billion. As they have self-limiting property, maximum permissible limits are not stipulated.

6.7 SWEETENERS

Sweetness is one of the important taste sensations. The importance of sweetness is reflected in huge production of sugar (sucrose) world over. Sucrose is not consumed only for its sweetness. It also has many functional properties in foods like a bulking agent, texture modifier, and preservative.

Like any other carbohydrate, sucrose is also a nutrient providing energy to the human system. Over the years, sucrose has been implicated in obesity development and associated diseases and also dental caries. Besides, diabetes has become a common disease among large sections of the population. As a result there is a general trend towards reducing energy intake. This has resulted in development of sucrose alternatives.

There are two types of sucrose alternatives viz. nutritive and non-nutritive sweeteners. Nutritive sweeteners also called calorie sweeteners are usually carbohydrates or carbohydrate derivatives. Non-nutritive sweeteners include a range of natural products and some synthetic chemicals.

6.7.1 Nutritive Sweeteners

You have already learnt about glucose, glucose syrup, fructose and high fructose syrup and their relative sweetness in an earlier unit. In this section you will be learning about a few other nutritive sweeteners.

Sorbitol: Sorbitol is a six carbon sugar alcohol that was originally found in the berries of mountain ash. It is chemically produced from glucose for commercial use. It is highly soluble in water (72% at 25^{o}C). Sorbitol has half the sweetness of sucrose.

As it has a much lower caloric content compared to sucrose, sorbitol is used as a sweetener for diabetic foods, sugar-free candies and chewing gums.

Xylitol: Xylitol (xylit) is a pentiol found in most fruits and berries as well as xylan (a polysaccharide) containing plant materials. It is also produced by microbiological methods. Xylitol is a crystalline substance, having good water solubility (64 % at 25^{o}C). It has sweetness and caloric content equal to sucrose. However, because xylitol is absorbed slowly, it does not cause increase in blood glucose level as glucose or sucrose. Therefore, it is used in diabetic foods also.

Isomalt: Isomalt is also called hydrogenated isomaltulose. It is an equimolar mixture of 6-0-β-D-glucopyranosyl-Dglusitol and 1-0-β-D-glucopyranosyl-D-mannitol. Isomalt is produced by the enzymatic transglucosidation of sucrose to isomaltulose and hydrogenation. It is of about half the sweetness of sucrose. It is stable in acid and alkaline media under conditions normally occurring in food processing. It has no impact on blood sugar. Isomalt is used as a sugar substitute in confectionaries, chewing gum, soft drinks and desserts.

6.7.2 Non-Nutritive Sweeteners

Saccharin: Saccharin was synthesised way back in 1879. During the two world wars, the use of saccharin as a sweetener increased due to the scarcity of sugar and became an accepted sweetener for special dietary and dietetic foods even though its safety has repeatedly been questioned.

Saccharin is a general name used for saccharin, sodium saccharin and calcium saccharin. Chemically saccharin is 1,2-benzisothiazol-3 (2H)-one-1, 1-dioxide. Saccharin and sodium saccharin are white crystalline powders soluble in water. They are about 500 times sweeter than sucrose. It has good stability during cooking and baking of food products but leaves a slight bitter metallic aftertaste. It is permitted as a sweetener in several countries including India with restrictions.

Available toxicological information does not conclusively implicate saccharin for any serious health hazard. The Acceptable Daily Intake (ADI by WHO) of saccharin is fixed at 2.5 mg/Kg body weight. However, as more and more research results accumulate, safer alternates for saccharin is bound to emerge.

Cyclamates: Although sodium cyclamate was synthesized in 1937, its actual use as a sweetener started only in 1950. Cyclamates is a group name used for cyclamic acid, sodium cyclamate and calcium cyclamate. They are synthesized from cyclohexylamine by sulphonation. They are not found in nature. Cyclamates are stable at high temperatures, are easily soluble in water. They are about 30 times sweeter than sucrose and can be used as a noncalorie sweetener in a variety of products. Some times it is used as a mixture along with saccharin.

Cyclamates are not without safety questions. Therefore its usage is only allowed with restrictions like most other non-nutritive sweeteners. The use of cyclamates is not permitted under PFA. Its ADI value is 11 mg/Kg body weight.

Aspartame: Aspartame was discovered only in 1960. It is the methyl ester of L-aspartyl-L-phenylalanine. Aspartame is produced from the amino acids phenylalanine and aspartic acid. It is an odourless white crystalline powder, slightly soluble in water and almost 150-200 times sweeter than sucrose.

Aspartame provides 4 Kcal/g energy. Aspsrtame provides sugar like sweetness in foods, but under certain moisture, temperature and pH conditions, it is hydrolysed and loses its sweetness. Therefore, aspartame is more suitable for dry products or as a table top sweetener although it is widely used in soft drinks, dairy products etc. Soft drinks are usually sweetened with a mixture of saccharin and aspartame.

Available evidence suggests that normal consumption of aspartame is safe because consumption of asprtame from foods is far below any suspected toxic levels. Its ADI value is fixed at 40-mg/Kg body weight. The use of asprtame is permitted in many countries including India.

Acesulfame K: Acesulfame K is one of the most recently introduced (1967) non-nutritive sweeteners. Acesulfame K is the potassium salt of 6-methyl-

1,2,3-oxathizine-4(3)-one-2,2-dioxide. It is a white crystalline powder, freely soluble in water, non hygroscopic and 150-200 times sweeter than sucrose. Acesulfame K is used in soft drinks, chewing gum and as a table-top sweetener. More food applications are being investigated.

The available toxicological data on acesulfame K do not show any serious safety implications. The ADI value is fixed at 9-mg/Kg body weight. Its use as a sweetener is permitted in some countries including India with restrictions.

6.8 MISCELLANEOUS ADDITIVES

The number of substances in this category though very large, is not used extensively in fruit and vegetable products. Therefore, only a few of them will be dealt with in this section. They include emulsifiers and stabilizers, firming agents, anticaking agents, clarifying agents etc.

Emulsifying and stabilizing agents are essentially used for emulsifying and stabilizing dispersions of oils and fats in aqueous media. They include different types of gums (you have learnt under 'carbohydrates'), esters of fatty acids, lecithin, ester gums (glycerol esters of wood rosin) etc.

Firming agents like calcium chloride are used to firm the texture of canned fruits and aluminium sulphate added to pickles.

Anticaking agents are used to impart free flowing properties to dry products. Examples are silicates in potato flakes, dehydrated vegetable powders, cocoa powders, salt; tricalcium phosphate in spices, and fruit powders; and starches in icing sugar etc.

Clarifying agents are used to clarify fruit juices and wines and chill proofing of beer. Gelatin is a typical example of a clarifying agent.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between natural and nature-identical flavouring substances.

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2. What is the difference between nutritive and non-nutritive sweeteners? Give three examples of each.

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3. Give one example each for Firming agent, Anticaking agent and Clarifying agent.

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6.9 LET US SUM UP

A large number of additives are used in foods for different functions. Some are used as preservatives, which prevent microbial spoilage while antioxidants preserve food against oxidative deterioration. Acidulants have dual roles of preservation as well as imparting the desired taste. Colourants and flavouring agents are added essentially to enhance the acceptability of foods. There are also other additives having functions like texture modification, clarification, imparting free flowing characteristics to food powders etc.

All the food additives are not free from suspected health hazards. Therefore, their use in foods is restricted by food legislations.

6.10 KEY WORDS

Additive : Substance added intentionally

Class I preservatives : Natural preservatives

Class II preservatives : Chemical preservatives

Antioxidant : Substance, which prevents oxidation

Nutritive sweeteners : Sweeteners having calorific value.

6.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Other than basic foodstuff
   - Added, not chance contaminant

2. Your answer should include the following points:

   - Class I and class II preservatives
   - Salt, sugar, spices, vinegar etc.

3. Your answer should include the following points:

   - Benzoates, sulphites, sorbates etc
   - Antimicrobial, anti browning

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Inhibit autoxidation of glycerides
   - Get oxidised in preference to fats and oils

2. Your answer should include the following points:

   - Tocopherols, ascorbic acids
   - BHA, BHT, TBHQ

3. Your answer should include the following points:

   - PH reduction
   - Buffering
   - Flavouring

4. Your answer should include the following points:

   - Ponceau
   - Carmoisine
   - Erythrosine
   - Sunset yellow etc

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Natural flavouring substances isolated by physical means
   - Chemically identical to natural substances but chemically isolated from aromatic substances or synthetically prepared

2. Your answer should include the following points:

   - Calorie sweeteners
   - Sucrose, glucose, fructose etc
   - Non calorie sweeteners
   - Synthetic
   - Saccharin, cyclamate, aspartame, acesulfame K

3. Your answer should include the following points:

   - Calcium chloride
   - Tri calcium phosphate
   - Gelatine

6.12 SOME USEFUL BOOKS

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UNIT 7 ETHYLENE LIBERATION AND ITS CONTROL

Structure

7.0 OBJECTIVES

After going through this unit, you should be able to:

- know the role of ethylene in fruit physiology;
- tell how ethylene is synthesized in fruit tissues;
- explain the mechanism of action of ethylene; and
- state the different methods to remove ethylene from storage rooms.

7.1 INTRODUCTION

Ethylene is the simplest chemical compound known to cause a significant physiological effect. It is also known as ripening hormone and is effective at very low concentration. Ripening is the result of complex changes; many of them probably occur independent of each other. Respiration and ethylene production are the two of the major processes occurring during ripening. Ethylene plays a role in post-harvest life of many horticultural crops, which is often deleterious, speeding senescence and reducing shelf life, but sometimes beneficial, improving the quality of the product by promoting faster, more uniform ripening.

Ethylene is a gaseous harmone with a characteristic suffocating sweetish odour. It is both an anaesthetic and asphyxiant. High vapour concentration can cause rapid loss of consciousness and perhaps death by asphyxiation. Removal to fresh air usually results in prompt recovery if the person is still breathing. When the gas is handled in liquefied form, skin and eye burns can result from contact with the liquid. Cases in which liquid ethylene contacts, a physician must see to the eye.

7.2 SOURCES OF ETHYLENE

Ethylene gas is relatively inexpensive industrial chemical, but it is often more convenient or safer to provide ethylene by means other than the gas. Regardless of the source of ethylene, the treatment conditions are important for the ripening process.

Explosion-proof Ethylene Mixtures

Using mixtures of ethylene with inert gases can eliminate the danger of explosions from oversupply of ethylene to a ripening room. The proportion of the inert gas should be such that at high concentrations of ethylene not enough oxygen remains in the ripening space to provide an explosive mixture. Ripegas, a commercial formulation of ethylene contains 6 percent C_2H_4 in CO_2 by weight.

Ethylene Generators

Ethylene generators, in which a liquid products ethylene when heated in the presence of a catalyst, are now widely used for supplying ethylene in ripening rooms. The liquid comprises of ethanol and agents that catalyze its dehydration.

Ethephon

Ethephon (2-chloroethyl phosphonic acid) is strongly acidic in water. In solutions above pH of about 5, the ethephon molecule spontaneously hydrolyses, liberating ethylene molecule. Ethephon is commercially available (Ethrel, Florel, Cepa) and is used for preharvest treatment on a variety of crops for controlling developmental processes, or inducing ripening. For enhancing postharvest ripening, it has the disadvantage as it has to be applied to the fruit in liquid form as a spray or as a dip. This extra step in handling may cause microbial infection. But compared to ethylene treatment, it has the advantage, as no special facilities are required to ripen fruit with ethephon, if the ambient temperatures are within the range required to ripen the commodity.

Calcium Carbide

Heating calcium oxide with charcoal, under reducing conditions, readily produces calcium carbide. When hydrolyzed, calcium carbide produces acetylene, containing trace amounts of ethylene that are sufficient to trigger fruit ripening. Simple generators can be used in partially vented spaces to ripen or degreen fruits. In some instances CaC_2 wrapped in newspaper can be used as the generator. Water vapour from the fruit releases sufficient ethylene from CaC_2 to cause ripening.

7.3 USES OF ETHYLENE

Post-harvest Uses

Post harvest uses of ethylene include its uses as ethephon, an ethylene-releasing chemical, as a growth regulator. Fruit ripening is by far the largest application of ethylene gas in post-harvest technology. Other uses of ethylene in crops include-

Flower and Sprout Induction

The stimulation of flowering of pineapples by ethylene treatment is important for pineapple industry. Japanese bulb growers discovered that iris bulbs from fields that had been burned at the end of the season to control leaf diseases flowered earlier and more prolifically than controls. It was found that smoke did the same for bulbs that had been harvested, and smoking of bulbs is still practiced in Japan. The active ingredient in the smoke is ethylene, and it has now been shown that ethylene treatment of the propagules of a number of flowering crops stimulates flowering. Narcissus bulbs normally do not flower without ethylene treatment, and treatment with ethylene for a few hours just after lifting induces almost 100 per cent flowering.

Ethylene is also used as a short treatment to enhance the sprouting of seed potatoes. Ethylene treatment breaks the dormancy of the buds, but prolonged treatment inhibits their extension growth.

Shuck Loosening and Fruit Release

Ethylene is also used to induce the abscission of leaves, flowers, and fruit from many plants. Pre-harvest application of ethylene to walnut and pecan trees induces shuck loosening and improves harvest efficiency. Similarly, these chemicals are used to loosen the abscission zone on the stalk of fruits that are mechanically harvested (e.g. sour cherries), for improving harvest yields.

Chlorophyll Destruction

In many plant tissues, ethylene treatment result in rapid loss of cholorphyll, the green colour in leaves and unripe fruit. This property is used for degreening of citrus, where the orange colour is revealed as the chlorophyll is destroyed during ethylene treatment. Ethylene also helps in bleaching of celery and accelerated curing of tobacco.

Fruit Ripening

The concentrations of ethylene (in the range of 0.1 to 1 ppm) are required for the ripening in most of climacteric fruits. The time of exposure to initiate ripening depends on type of fruit, but usually exposures of 12 hours or more are usually sufficient. Full ripening sometimes takes several days after the ethylene treatment. The effectiveness of ethylene in achieving faster and more uniform ripening depends on the type of fruit being treated, its maturity, the temperature and relative humidity of the ripening room, ethylene concentration and duration of exposure to ethylene.

Control of temperature is critical to good ripening with ethylene. Optimum ripening temperatures are 18° to 25°C. At lower temperatures ripening is slowed; at temperatures over 25°C bacterial growth and rotting may be accelerated, and above 30°C ripening may be inhibited. Fruit that have been cool-stored must be warmed to 20°C to ensure that ripening proceeds rapidly. As ripening starts, the burst of respiration can generates heat, therefore it is essential to ensure that this heat does not increase pulp temperatures to the point where ripening is inhibited

7.4 ETHYLENE AS RIPENING INDUCER

Ethylene is regarded as an agent that can induce ripening. It has been established that all the fruits produce minute quantity of ethylene during development, but climacteric fruits produce much larger amounts of ethylene as compared to non-climacteric fruits during ripening. Further, the internal ethylene concentration of climacteric fruits varies widely, but that of non-climacteric fruits changes little during development and ripening. A concentration of 0.1-1.0 μl/l ethylene for one day is sufficient to hasten ripening of climacteric fruits, but the magnitude of climacteric is relatively independent of the concentration of ethylene. In contrast, applied ethylene merely increases the respiration of non-climacteric fruits, and the magnitude of increase depends upon the concentration of ethylene. Further, the rise in respiration in response to ethylene may occur more than once in non-climacteric fruits in contrast to single respiration increase in climacteric fruits.

The significance of ethylene for fruit ripening was established during the early part of this century when heaters burning kerosene were used to degreen or colour yellow lemons. Ethylene was regarded as an external agent that could promote the ripening of fruit, and other plant tissues, produced extremely small quantities of ethylene.

7.5 BIOGENESIS OF ETHYLENE

It was shown that application of an amino acid methionine greatly stimulated ethylene production in apples, and this compound was then considered to be the starting point for ethylene biosynthesis. Then s-adenosyl-methionine (SAM) was identified as another important compound in pathway, which is converted to 1-aminocyclopropane-1-carboxylic acid (ACC). ACC is now regarded as the immediate precursor for ethylene and ACC synthase controls the rate at which pathway operates. ACC synthase is activated by an enzyme cofactor, known as pyridoxal phosphate. Inhibitors of enzyme that require pyridoxal phosphate, such as aminoethoxy vinyl Glycine (AVG) and amino-oxyacetic acid (AOA) can be used to inhibit ethylene production.

It is generally agreed that the amino acid methionine is the precursor of ethylene in plants, with the conversion having an absolute requirement for molecular oxygen. Small amounts of ethylene probably can also be formed in plant tissues from the oxidation of lipids involving a free radical mechanism. As yet, the ethylene-producing system has not been isolated from fruit tissues for in vitro studies and the site or the organelle where ethylene is synthesized is still not very clear. The unravelling of the bio-chemical pathway of ethylene biosynthesis in plants has been one of the most interesting bio-chemical stories of recent years. Application of the amino acid, methionine greatly stimulated ethylene production in apples, and this compound was then considered to be the starting point for ethylene biosynthesis. Researchers at Davis, USA identified SAM (S-adenosyl-methionine) as another key compound in the pathway and then, almost simultaneously, Amrhein in West Germany and Adams and yang at Davis, USA discovered that SAM was converted to an unusual cyclic amino acid, ACC (1 aminocyclopropane-1-Carboxylic acid) which is now thought to be the immediate precursor for ethylene.

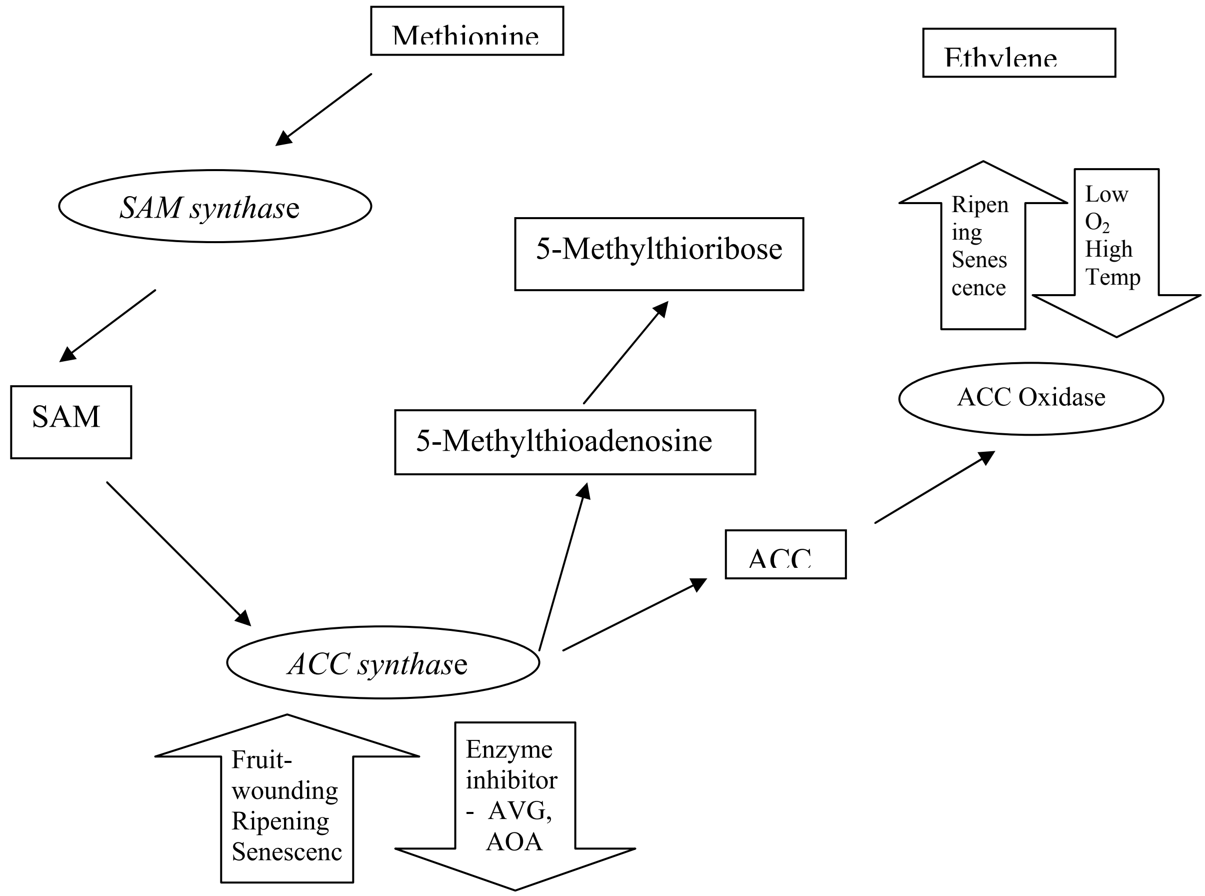

Figure 7.1: Biosynthetic pathway of ethylene

The enzyme which controls the rate at which the pathway operates, ACC synthase, is activated by a common enzyme co-factor, pyridoxoal phosphate such as AVG (amino-ethoxyvinyl gylcine) and AOA (aminooxyacetic acid) which inhibit ethylene production. Cobalt ion and low O_2, which inhibit the final step in the pathway, the Acc oxidase can also reduce ethylene production.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the precursor of ethylene biosynthesis.

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2. How ethylene effect differs in climacteric and non-climacteric fruits?

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3. What is the role of ethylene in post-harvest life of horticultural produce?

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4. Name the factors regulating action of ACC synthase enzyme?

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7.6 MECHANISM OF ETHYLENE ACTION

Although applied ethylene will initiate the ripening of climacteric fruits and will cause some ripening like changes in non-climacteric fruits similar to those in senescing tissue, it has not been possible to prove that ethylene acts in vivo as a true plant hormone, that is, acts in fruit tissues at trace levels, in promoting and controlling fruit ripening. A considerable amount of circumstantial evidence is available which suggests that ethylene, probably in concert with the other plant hormones (auxins, gibberellins, kinins and abscisic acid) exercises hormonal type control over the fruit ripening process. The relationship of the other plant hormones to ripening is as yet not clearly defined.

In some fruits, such as banana, avocado and melons, there is a small rise in endogenous (internally produced) ethylene concentration preceding the commencement of the respiratory climacteric. For example, the internal ethylene concentration of Honey Dew melon rises from the pre-climacteric level of 0.04 microlitre/litre to 3.0 microlitres/litre at which concentration the fruit commences to ripen. Other fruits, such as mango and apple, do not show this rise in internal ethylene concentration before ripening. Once ripening has commenced, the large amount of ethylene synthesized by climacteric fruits is thought necessary to promote all of the aspects of ripening.

It is well known that many fruits as they develop and mature, become more sensitive to ethylene. For sometime after anthesis (flowering) young fruit can have high rates of ethylene production. Early in the life of fruit can have high rates of ethylene production. Early in the life of fruit the concentration of applied ethylene required to initiate ripening is high and the length of time to ripen is prolonged, but decreases as the fruit matures. The tomato is an extreme case of tolerance to ethylene. Banana and melons, in contrast, can be readily ripened with ethylene even when immature. Nothing is known about the factors that control the sensitivity of the tissue to ethylene.

There is also no clear evidence to suggest the mechanism by which ethylene initiates and controls fruit ripening and little is known about the site of action of ethylene and the mechanism by which ethylene either promotes ripening or increases respiration in non-climacteric fruits or in other tissues such as the potato tuber. Ripening has long been considered to be a process of senescence and to be due to a breaking down of the cellular integrity of the tissue; some ultrastructural and bio-chemical evidence supports this view. There is now considerable evidence for ripening being a phase in the differentiation of plant tissue, with altered nucleic acid and protein synthesis occurring at the commencement of the respiratory climacteric. Both views fit in with the known degradative and synthetic capacities of fruit during ripening, but this type of study is unlikely to determine how ethylene initiates ripening.

Although applied ethylene initiates ripening in fruits, it is not proved how ethylene acts in vivo as a true plant hormone. Some evidence suggests that probably in combination with other hormones it exercises hormonal type control over the fruit ripening process. Some fruits show a rise in internal ethylene concentration before ripening, whereas others do not. The factors that control the sensitivity of the tissues to ethylene are yet to be known. But once ripening has commenced the large amount of ethylene produced by climacteric fruits is thought to be necessary to promote all aspects of ripening. It has been proposed that two systems exist for the regulation of ethylene biosynthesis. System I is initiated or perhaps controlled by an unknown factor, probably involved in the regulation of senescence. System I then triggers system II, which is responsible for production of large amounts of ethylene in climacteric fruits. Non-climacteric fruits lack an active system II.

Recently a model for the way in which ethylene induces a host of effects was introduced. According to this ethylene binds to a protein, called a binding site, and stimulates the release of a so called second message instructing the DNA to form mRNA molecule specific for the effects of ethylene. These molecules are translated into protein by polyribosomes, and the proteins so formed are the enzymes that cause the actual ethylene response.

7.7 ETHYLENE TREATMENT SYSTEMS

For ethylene treatment ripening rooms or specially built chambers with automatic control of temperature, humidity, and ventilation are used. It is not essential that the rooms be hermetically sealed, but they should be as tight as practicable to prevent leakage. Because of the rapid increase in respiratory heat production following ethylene treatment, ripening rooms should be equipped with refrigeration systems adequate to hold the temperature.

Several methods are used to provide the proper ethylene concentration in the ripening room.

The "shot" System

In the shot system, measured quantities of ethylene are introduced into the room at regular intervals. The shots may be applied by weight, or by flow. The required ethylene application is made by adjusting the regulator to give an appropriate flow rate and, the time of delivery of the gas. Any piping leading into the ripening room should be grounded to prevent possible electrostatic ignition of the explosive concentrations of ethylene that are always present near the orifice when ethylene is being introduced. Sometimes the ethylene is administered by weight also.

Because the room containing the product being ripened is sealed in the shot system, CO_2 accumulates in the room and may inhibit the ripening process. Therefore the room should be well ventilated before each application, particularly if it is well sealed, by opening the doors for about half an hour. In large ripening rooms, ventilating fans should be provided. Where the ripening rooms are near rooms used for storage or handling of ethylene-sensitive commodities, the room should be ventilated to the exterior to prevent contamination.

The Trickle or Flow-through System

The ethylene is introduced into room continuously, rather than intermittently. As the flow of ethylene is very small, it has to be regulated carefully. This is usually done by reducing the pressure using a two-stage regulator and passing the gas into the room through a metering valve and flowmeter.

To prevent a build up in either CO_2 or C_2H_4 fresh air is drawn into the ripening room at a sufficient rate to ensure a change of air every 6 hours. The air is vented through a small exhaust port to the rear of the room.

A convenient way of monitoring gas being supplied in a trickle system is a simple "sight glass" in which, the ethylene bubbles through a water trap on its way to the ripening room. As in the shot system, correct temperature maintenance and adequate air circulation are essential for good ripening.

7.8 CONTROL

Ethylene is produced whenever organic materials are stressed, oxidized or combusted. There are many sources of ethylene pollution during post-harvest handling of perishables, but the most important are internal combustion engines, ripening rooms and ripening fruits. Other sources are aircraft exhaust, decomposing produce and sometimes fungi growing on it, cigarette smoke, rubber materials exposed to UV light and virus infected plants. Sometimes ethylene contamination of flowers takes place from propane-powered floor polishers. The undesirable effects of ethylene that must be controlled are as follows:

Accelerated Senescence

In green tissues, ethylene commonly stimulates senescence, as indicated by loss of chlorophyll, loss of protein, and susceptibility to desiccation and decay. Ethylene pollution can result in yellowing of leafy vegetables (spinach, fresh herbs, parsley, broccoli and other green vegetables). The senescence of some flowers is also stimulated by ethylene at very low concentrations. These effects occur in flowers where increased ethylene production is part of natural senescence (sweet peas) and in others where it is not a part of natural senescence (roses).

Accelerated Ripening

Although acceleration of ripening is a beneficial use of ethylene, it can also be undesirable, as the presence of ethylene in the cucumber causes premature yellowing. Most climacteric fruits senescence faster if ethylene is present in the atmosphere, therefore ethylene in the storeroom may reduce storage life. The firmness of kiwi fruit in storage was dramatically reduced at 20 ppb ethylene concentration in the cool store.

Induction of Leaf Disorders

In many plants, exposure to ethylene results in darkening or death of portions of their leaves. This response is commonly seen in foliage plants and is of major economic consequence in lettuce, where ethylene causes the disorder known as russet spotting. In lettuce, the browning results from collapse and death of areas of cells following increased synthesis of phenolic compounds in response to ethylene.

Sprouting

The ethylene-stimulated sprouting is useful in propagules, but undesirable in commodities intended for consumption. Sprouting of potatoes increases water loss, leading to early shriveling and makes them unmarketable.

Abscission of Leaves, Flowers and Fruits

Ethylene induced abscission is most often a problem in ornamental plants, where low concentrations can cause complete loss of flowers or leaves. The Christmas cactus is sold when the first flowers are open, but exposure to ethylene may cause all the flowers fall in the bottom of the box during transportation.

Toughening of Asparagus

Ethylene stimulates the lignification of xylem and fiber elements in the growing asparagus spear, leading to undesirable touchiness and reducing the portion of the spear that is edible.

Induction of Physiological Disorders

Ethylene sometimes induces or hastens the appearance of physiological disorders of stored commodities. Rapid ripening of apples with low calcium contents induces high levels of the bitter pit storage disorder. Similarly, high ethylene levels in the storage chamber reduce the effectiveness of controlled atmospheres in maintaining quality of apples. While useful in inducing flowering in bulbs and other propagules, ethylene damages these propagules after the flowers have started to develop.

A number of techniques have been developed to protect sensitive commodities from the effects of ethylene. Selection of the appropriate method obviously depends on the commodity and the handling techniques used in its marketing.

Removing ethylene from the atmosphere around the commodity is the preferable method of preventing deterioration of ethylene sensitive products. Most of the times, removing the sources of ethylene can do it. Combustion gases exhaust should be avoided from handling and storage rooms. A good sanitation by removing overripe and rotting produce will help in reducing ethylene levels. Ventilation of storage rooms can also help in reducing ethylene concentration.

Eliminating Sources of Ethylene

High levels of ethylene in storage and handling areas can be avoided by removing sources of ethylene. In particular, commodities sensitive to ethylene, should be handled using electric forklifts. Internal combustion engine vehicles should be isolated from handling and storage areas and engines should never be left idling in an enclosed space during loading and unloading operations. Where these techniques are not feasible, it is possible to fit combustion engine exhausts with catalytic converters, which will reduce C_2H_4, emissions by 90 percent. Rigorous attention to sanitation will remove overripe and rotting produce which can be a source of ethylene.

Ventilation

Where the air outside storage and handling areas is not polluted, simple ventilation of these areas can reduce ethylene concentrations. An exchange rate of one air change per hour can readily be provided by installing an intake fan and a passive exhaust.

Chemical Removal

Ethylene can be removed by a number of chemical processes; the most important are described below:

- Using potassium permanganate
- Using ultraviolet lamp (by ozone)
- Activated or brominated charcoal
- Catalytic oxidizers

Potassium permanganate: Commercial materials, such as Purafil, utilize the ability of potassium permanganate ($KMnO_4$) to oxidize ethylene to CO_2 and

H_2O. The requirements for such materials are a high surface area coated with the permanganate and ready permeability to gases. Many porous materials have been used to manufacture permanganate absorbers, including vermiculite, pumice and brick. The type of material may depend on the purpose for which the absorber is required. For removing ethylene from room air, the absorber should be spread out in shallow trays, or air should be drawn through the absorber system.

Ultraviolet lamps: Commercial equipment for ultraviolet lamps draws the air from the storage room through the lamps. Ultraviolet lamps produce ozone, which is an active ethylene-removing agent. As the ozone produced by the lamps is very toxic to fresh produce, it must be removed from the produce.

Activated or brominated charcoal: Charcoal air purifiers, especially if brominated, can absorb ethylene from air. These systems are largely confined to use in the laboratory, as potassium permanganate absorbers are cheaper and more widely available.

Catalytic oxidizers: If ethylene and oxygen are combined at high temperature in the presence of a catalyst (e.g. platinized asbestos) the ethylene will be oxidized. Ethylene scrubbers overcome the difficulty of heating the incoming air by using the bed of ceramic as a heat sink and reversible flow of gas through the bed. These scrubbers are very efficient in reducing the ethylene concentration in the air to 1/100th of original concentration.

Bacterial systems: Approximately 30,000 metric tons of ethylene is liberated into the atmosphere each day from internal combustion engines, but the concentration of ethylene in air remains very low. The bacteria that use ethylene as a bio-chemical substrate are able to remove ethylene from the atmosphere.

Hypobaric Storage

Hypobaric storage helps in reducing the levels of ethylene as the relative concentration of all the gases in storage room goes down. Many of the benefits of hypobaric storage are due to reduction in the partial pressure of oxygen, which accompanies reduction in the atmospheric pressure.

Inhibition of Effects of Ethylene

Sometimes it is not possible to ensure low concentration of ethylene. In such cases attempts should be made to inhibit the effect of ethylene. Different techniques used are:

- Controlled atmosphere storage
- Use of antiethylene compounds (NBD, STS)
- Inhibition of ethylene biosynthesis

Controlled atmospheres: Low concentrations of O_2 and high concentrations of CO_2 in the storage atmosphere reduce the rates of respiration, ethylene production and other metabolic processes. CO_2-enriched atmospheres also may inhibit the action of ethylene on tissues sensitive to it. Accumulation of CO_2 produced by the fruits may help in preventing the action of ethylene.

Use of anti-ethylene compounds: Compounds that inhibit the action of ethylene include silver ion and 2, 5 norborneadiene (NBD). Complex between silver and thiosulfate (STS) is being used for ornamental commodities. It has a very low stability constant and therefore it moves readily from the vase solution to the head of cut flowers. Flowers pulsed with this material last two to three times as long as control flowers. Potted flowering plants do not lose their flowers during transportation if they are first sprayed with STS.

Inhibition of Ethylene Biosynthesis

Ethylene may reduce quality even when it is not present as a pollutant if the tissue itself produces ethylene. Inhibitors of ethylene biosynthesis, such as AVG and AOA have been used in laboratory experiments to extend flower vase life and fruit storage life but not on commercial scale.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write the mechanism of ethylene action?

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2. How hypobaric storage helps in controlling ethylene?

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3. Name the chemical processes that can remove ethylene from storage environment.

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4. How one can minimize the deleterious effects of ethylene?

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7.9 LET US SUM UP

Ethylene, a ripening hormone plays an important role in post-harvest life of many commodities. Sometimes its effect are beneficial where it is used for uniform ripening or degreening, but mostly it is considered deleterious as it hastens senescence and reduces post-harvest life. Simple practices of good sanitation and ventilation of storage room can help in reducing ethylene concentration. Use of chemicals or advanced storage techniques can also reduce the deleterious effects of ethylene.

7.10 KEY WORDS

Physiology	:	Study of the functions and vital processes of living organisms or their parts.
Ethylene	:	A colourless flammable gas which stimulates ripening.
Ripening	:	The advance stage in the development at which fruit and vegetable are suitable for consumption/ utilization.
Climacteric	:	Fruits/vegetables showing a sudden upsurge in respiration couples with ethylene evolution.
Non-climacteric	:	Fruits/vegetables who do not show a sudden upsurge in respiration couples with ethylene evolution.
Biosynthesis	:	The formation of chemical compounds by the enzyme action of living tissues.
Hormone	:	A substance which is synthesized at one tissue and has specific effect on another tissue.
Ventilation	:	To circulate fresh air or drive out foul air.
Hypobaric	:	Less than normal air pressure.
Degreening	:	Removal of chlorophyII pigment form the tissue.

7.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:
   - Amino acid
   - Methionine
2. Your answers should include following points:
   - Ethylene concentration
   - Increase in respiration
3. Your answers should include following points:
   - Senescence
   - Decolourization
4. Your answers should include following points:
   - Wounding
   - Ripening
   - Enzyme inhibitors

Check Your Progress Exercise 2

1. Your answers should include following points:
   - Binding site
   - Polyribosomes
2. Your answers should include following points:
   - Relative concentration
   - Oxygen level
3. Your answers should include following points:
   - Potassium permanganate
   - UV rays
   - Charcoal
4. Your answers should include following points:
   - Controlled atmosphere
   - Antiethylene compounds

7.12 SOME USEFUL BOOKS

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UNIT 8 GROWTH, MATURATION AND SENESCENCE

Structure

8.0 OBJECTIVES

After going through this unit, you should be able to:

- know the chemical changes taking place during growth, ripening and senescence;
- tell about respiratory climacteric;
- explain the factors affecting respiration; and
- mention the morphological changes in fruit tissues during ripening and senescence.

8.1 INTRODUCTION

The life of fruits and vegetables can be divided into three major physiological stages following germination- growth, maturation and senescence. Ripening is considered to begin during the later stages of maturation and to be the first stage of senescence. Development and maturation of fruit are completed only when it is attached to the plant, but ripening and senescence may proceed on or off the plant. Major changes in carbohydrates, organic acids, pigments and volatiles are observed during growth of the produce, which continue during ripening and senescence.

Food may be stored in various storage organs, such as roots, shoots tubers, rhyzomes, bulbs, corms, fruits and seeds. Storage may take place at different seasons of the year and may in some plants be controlled by the length of the day, the length of the night period and the day & night temperatures. In many plants that live for more than one season (perennials), accumulation in the underground storage organs takes place at a rapid rate in the fall of the year.

Fresh fruits, as well as fresh vegetables are essential components of human diet. Both contain a number of nutritionally important compounds, such as vitamins, which cannot be synthesized by the human body; vitamin C is the most important and essential nutritive substance found mainly in fruits and vegetables.

The fruits are used as a table commodity whereas the vegetables are usually cooked and then served as food. Some of the vegetables are "fruit-vegetables" and most of the vegetables are the other vegetative organs of the plant that include root, stem, flower, shoot, leaves and associated parts.

Fruits and vegetables are highly perishable products with active metabolism during the post-harvest period. Proper handling plays an important role in increasing their availability. On removal from the parent plant, vegetative parts, such as fruits, roots, stems etc are deprived of their normal supply of minerals, water, and also in some instances, simple organic molecules [e.g. sugars, hormones] that normally would be translocated from other parts of the plant. Innumerable physiological and biochemical processes are initiated and continued in the edible plant tissues at the time of harvest. Although the photosynthetic activity is negligible, most tissues remain capable of transforming many of the constituents already present in them. The diversity of metabolic shifts, which are specific to a given commodity [and often variety] are manifest in events such as 'rotting', 'ripening', 'sprouting', 'scald', 'brown core', 'hard core', 'toughening', and 'yellowing'.

The kind and intensity of physiological activity in detached plants determines their storage longevity. Some plant parts, such as seeds, fleshy roots, tubers, bulbs are morphologically and physiologically adapted to maintain the tissue in a dormant state until environmental conditions becomes favourable for germination or growth. Metabolic activity, though depressed, is not completely halted in such tissues. Fleshy fruits are unusual in that maturation is followed by a ripening process, which is associated with the development of optimal eating quality.

The diversified visible physiological changes, like sprouting, browning, toughening etc are desirable in some commodities and undesirable in others in relation to the eating quality. Almost all such changes are observed during ripening.

Physiology of Ripening

The term "ripening" is generally referred to the physical and biochemical changes taking place in the fruits after the cessation of growth till the onset of senescence and decay. The ripening process is dependent upon maturity, since a given stage of development must be attained before ripening progresses. The process of ripening continues while the fruit is on the tree, but the damage caused by the birds, insects etc makes it uneconomical to allow it to ripen on the tree. Hence, the fruits are usually harvested at the horticulturally mature stage. Fruits being living entities continue to carry on the normal physiological processes resulting in the ripening and finally decay or death of the fruit even after they are separated from the parent plant/tree. Most of the fruits show the ripening changes after harvest with a few exceptions like grapes, which are to be ripened only on the vine, as they do not ripen well after harvest. Since the changes taking place in a fruit during ripening greatly influence the eating quality and the monetary value of the commodity depends on it, a detailed knowledge of the physiology and biochemistry of ripening is desirable for the successful storage and marketability of fruits.

8.2 PHYSICOCHEMICAL CHANGES DURING GROWTH OF STORAGE ORGANS

Carbohydrate

Sugars are important for pleasing fruit flavour (sugar acid ratio) and texture. As the ripening starts these sugars undergo metabolic transformation both quantitatively and qualitatively. Most of the soluble carbohydrates are metabolized completely as the fruit ripens. Pectic substances and cellulose are the reserve carbohydrates that also serve as potential sources of acids, sugars and other respiratory substances during ripening.

Many changes occur in carbohydrate fraction of fruit during ripening, the climacteric and senescence. Green or raw fruit usually contains starch in abundance, but is short of soluble sugars that provides sweetness to it. During ripening, the starch is enzymatically [hydrolysis by alpha- and beta-amylases] converted into sugars. Thus, the major bulk of carbohydrate fraction of a fully ripened fruit consists of sugars. The sugars commonly found in fruits are glucose and fructose [invert sugars] and sucrose.

Organic Aacids

The organic acids are among the major cellular constituents undergoing changes during ripening. In most of the fruits there is a considerable decrease in the acidity of fruits during ripening.

The sourness of fruits is due to the presence of organic acids like citric, malic, succinic, tartaric, oxalic etc. These acids usually decide the quality of fruits as the blending of sugar and acids render the fruits tasty, besides flavour. Though these organic acids are present in varying amounts in raw or unripe fruits, but the concentration considerably changes as the fruits ripen. In fruits like oranges, the acids are converted enzymatically into sugars rendering them sweet as they ripen, whereas there is no change in lemons. So they remain sour till they start decaying. But, in some fruits like mangoes, there is a considerable decrease in acidity when the fruits fully ripen. This is partly due to the utilization of these acids in respiration through Kreb's Cycle. Generally, in fruits the total acidity shows a decrease with the increase in ripeness of the fruits.

Amino Acids and Proteins

A major turnover of amino acids in mango takes place during ripening, whereas in carombola shows a continuous decline. Small increase in protein content was also observed in mango, tomato and avocado.

The nitrogen content of fruit is due to proteins forming insoluble fraction and the soluble fraction comprised of amino acids. The total nitrogen content of fruits at the early stages is high, but with the advancement in growth, shows gradual decrease. This is probably due to increase in other constituents like water, starch, sugar, organic acids etc. During ripening, the total nitrogen may show a further decrease in some cases.

Lipids

Phospholipids occur in the cytoplasm and in many structural units of plant tissues. They are physiologically more important than neutral lipids in storage organs. Considerable increases in the level of total lipids and fatty acids have been observed in ripening mango in contrast to many fruits and vegetables. However in fatty fruits of avocado the oil composition during maturation remains more or less constant.

Chlorophyll

Disappearance of green colour marks the initiation of ripening in most of the fruits. Chlorophyll content of ripening fruit decreases universally.

Carotenoids

A dramatic synthesis of carotenoids occurs during the last step of ripening. It has been reported that the levels of carotenes, free geraniol, mevalonic acid, all precursors of carotene biosynthesis increases progressively during ripening.

Other Pigments

The colour imparted to raw or ripe fruits and vegetables are due to presence of various pigments. The pigments of different tissues are the chlorophylls (green), anthocyanin [reddish to purple], flavonoids [yellow], leucoanthocyanins [colourless], tannins [colourless to yellow or brown], betalains [red], quinones and xanthones [yellowish] and carotenoids [yellow and red].

During storage, some of these pigments undergo considerable changes. Carotenoids formation and destruction may be affected by the storage conditions. In certain instances, these reactions are stimulated by O_2, inhibited by light and high temperature. Carotenoids include lycopene, alpha, beta and gamma carotenes are synthesized enzymatically in the fruits. Anthocyanin synthesis is stimulated by light and is often affected by temperature. Purple colour of red cabbage intensifies when stored below 10^o C. Chlorophyll degradation is accompanied by synthesis of other pigments as the fruits ripen. Chlorophyll metabolism is markedly influenced by environmental parameters, such as light, temperature and humidity and the effects of these factors are specific for the tissues. For example, light accelerates degradation of chlorophyll in ripening tomatoes and promotes formation of the chlorophyll pigment in cold stored potatoes.

Tannins

The tannins and other polyphenolic constituents are present in abundant quantities in immature, raw or developing fruits. As the maturity and ripening progresses the total polyphenolic content reduces gradually.

Pectic Substances

The most obvious change during ripening of fruit is the alteration in texture. The plant cell wall is made up of cellulose fibrils embedded in a matrix consisting largely of pectic substances, hemicellulose, proteins, lignins etc and water. Cell wall and middle lamella components increase during development of fruits, but as the fruit ripens the content of soluble pectates and pectinates increase, while total pectic substances decrease.

The cell walls are surrounded by parenchymatous cells which will absorb water and generate hydrostatic pressure within the living cells. This is called tugor pressure which gives the desirable property of crispness to the commodity. During storage, the loss of moisture due to transpiration and respiration results in the loss of crispness or the turgidity of the commodity. In addition, the changes in the pectic substances (which forms a component of the cell wall of the fruit cells) account for the firmness of the fruits. During ripening, the proto-pectin, which is insoluble and forms, the middle lamella of the cell wall, decreases in quantity and the soluble pectin content rises, thereby making the flesh less firm or soft. A decrease in the chain length and loss of methyl groups of proto-pectin probably occurs during ripening, accounting for the rise in soluble pectin. This is brought about enzymatically mainly by the activity of the enzymes pectinase and pectin methyle esterase.

Volatile Products

Each fruit has specific aroma which ripened fruit emanates. Although different fruits vary in nature of volatile compounds, they are emitted in noticeable amount only when the fruit starts ripening. Although the degree of maturity is the main physiological factor affecting aroma production, the aroma composition is also affected by environmental conditions during maturation. In overripe fruits mostly alcohol and esters are formed when fermentation develops.

One of the marked differences between an unripe and ripe fruit is the intensity of flavour of the fruit. The flavour of fruits or vegetables are considered to originate by the presence of basic constituents, such as carbohydrates (particularly mono- and disaccharides], proteins [particularly free amino acids] and fats [triglycerides or their derivatives], as well as vitamins and minerals. These constituents are produced through photosynthetic and related metabolic activities occurring in the commodities. Some volatile compounds may exist in the tissues as such but in some it may be formed enzyatically upon rupture of cells or by microorganisms. Besides ethylene, a number of other volatile odorous constituents like amyl esters of formic, acetic, valeric and caprylic acids have also been identified. These organic emanations produced during ripening of fruits contribute to the aroma of fruits and hence are of considerable importance from the standpoint of fruit quality.

Enzymes

Enzyme action is responsible for many chemical and physical effects during ripening. Softening of fruits, conversion of starch to sugar or vice versa, changes in amino acid content, and in colour.

Most of the biochemical changes occurring in fruits during ripening can be attributed to enzyme reactions. The change from starch to sugar, sucrose to invert sugar or protopectin to pectinic acid are all due to enzymic reactions.

Oxidative enzymes like catalase and peroxidase were shown to have increased to a considerable extent in 'Alphonso' and 'Neelam' varieties of mangoes during ripening as indicated by the higher rate of respiration. Similarly, glycolytic and hydrolytic enzyme activity was also found to increase in ripening mangoes, particularly during climacteric and post-climacteric period. Aspartie aminotransterase activity also increased in mangoes, resulting in the increased amounts of amino acids. Chlorophyllase activity followed the climacteric pattern in bananas, but suggested that the ensuing chlorophyll degradation may not be relevant to ripening. Other enzyme that increases in activity during ripening and following respiratory climacteric is fatty acid synthatase in Avocado fruit.

8.3 MECHANISM OF NUTRIENT MOBILIZATION AND ACCUMULATION

A developing commodity is the complex system of actively metabolizing tissue. Fruit growth generally starts by a short but rapid cell multiplication followed by cell enlargement. Initially cell division and enlargement contribute towards growth, but later cell division becomes major contributory factor. Large quantity of food is accumulated in storage tissue, the composition of which varies with the type of produce. Starch is stored in potato, garlic, banana; fat in avocado; malic acid in apple; citric acid in citrus and pineapple; ascorbic acid in guava; tartaric acid in grapes. Although the nature of chemical stored is a genetic characteristic, the mechanism of storage is physiologically controlled.

Concentration gradient is partly responsible for movement of nutrients from leaves to storage organs. Soluble carbohydrates from leaves are converted to insoluble carbohydrates in storage structure, thus create a gradient for further accumulation. Organic acids are contained inside the vacuoles. Once products are accumulated inside the organ some form of controls occurs to prevent their drain.

Some hormones are involved in the nutrient accumulation in storage organs. Stimulation of nucleic acid and protein synthesis by hormone treatment may cause translocation of nutrients, which establishes a physiological sink.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What changes in carbohydrates take place during growth and ripening of the product?

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2. What is the effect of ripening on chlorophyll and carotenoids?

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3. What kind of food is stored in banana, apple, grape and guava?

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4. How carbohydrates are accumulated in tissues?

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8.4 RESPIRATION AND RESPIRATORY CLIMACTERIC

A major metabolic process occurring in harvested produce or in any living plant product is respiration. Respiration can be described as the oxidative breakdown of the more complex materials normally present in cells, such as starch, sugars and organic acids, into simpler molecules, such as carbon dioxide and water, with the concurrent production of energy and other molecules which can be used by the cell for synthetic reactions. Respiration can occur in the presence of oxygen (aerobic respiration) or in the absence of oxygen (anaerobic respiration, sometimes called fermentation).

Respiration rate of produce is an excellent indicator of metabolic activity of the tissue and thus is a useful guide to the potential storage life of the produce. If the respiration rate of a fruit or vegetable is measured as either oxygen consumed or carbon dioxide evolved – during the course of its development, maturation, ripening and senescence periods, a characteristic respiratory pattern is obtained. Respiration rate per unit weight is highest for the immature fruit or vegetable and then steadily declines with age. A significant group of fruits that includes tomato, mango, banana and apple shows a variation from the described respiratory pattern in that they undergo a pronounced increase in respiration during ripening. Such an increase in respiration is known as a respiratory climacteric and this group of fruit is known as the climacteric class of fruits. The intensity and duration of the respiratory climacteric, varies widely amongst fruit species. The commencement of the respiratory climacteric coincides approximately with the attainment of maximum fruit size and it is during the climacteric that all the other characteristic changes of ripening occur. The respiratory climacteric, as well as the complete ripening process, may proceed while the fruit is either attached to or detached from the plant. Those fruits such as citrus, pineapple and strawberry that do not exhibit a respiratory climacteric are known as the non-climacteric class of fruits. Non-climacteric fruits exhibit most of the ripening changes, although these usually occur more slowly than those of the climacteric fruits. All vegetables can also be considered to have a non-climacteric type of respiratory pattern.

Respiration Rate

Respiration is the process by which stored complex materials are broken into simple products and energy is released. While respiration is essential to maintain the state of living of the produce, it causes deterioration due to losses in food reserves, food value, flavour, and dry weight. The rate of deterioration of harvested produce is generally proportional to their respiration rate. Respiration is linked to many quality parameters, which are responsible for spoilage. The rate of respiration is a good index of post-harvest life of fruits and vegetables as it is directly related to the rate of metabolism. According to respiration rate commodities can be classified as-

Class	Respiration rate (mg CO_2/ Kg/h at 5°C)	Examples
Very low	5	Nuts, dates, dried fruits and vegetables
Low	5-10	Apple, citrus, grape, garlic, onion, potato
Moderate	10-20	Apricot, banana, cherry, peach, plum, pear, cabbage, carrot, tomato, pepper
High	20-40	Strawberry, blackberry, cauliflower, lima beans
Very high	40-60	Snap beans, Brussels sprout
Extremely high	>60	Asparagus, mushroom, pea, spinach

Respiratory Climacteric

Many fruits and vegetables show a rapid increase in respiration during ripening and they are called as climacteric. Fruits that do not show such phenomenon are referred as non-climacteric. Although non-climacteric fruits are also reported to have rise in respiration rate with a concomitant rise in ethylene production or may show this effect at appropriate stage or under appropriate storage condition.

Factors affecting Respiration

A number of factors are responsible for variation in respiration rate. They include internal factors such as stage of development and chemical composition of fruit tissues. External conditions also change respiration rate of the produce.

Stage of Development

During development as fruit size increases the total amount of CO_2 emitted by fruit also increases. In climacteric fruits, the respiration rate is minimum at maturity and remains rather constant, even after harvest. When ripening is about to start, respiration rate rises up to climacteric peak, then it slowly declines. Non-climacteric fruits ripen on tree, and if harvested early, a decline in respiration rate is observed. Actively metabolizing tissue has higher respiration rate. Small sized tissues will have higher respiration rate as they are having larger total surface area.

Chemical Composition of Tissue

The relationship between respiration rate and chemical composition varies among produce. Respiratory quotient varies with the type of substrate being used for respiration. It is 1 when substrate is sugar and less or more than 1 when lipids or organic acids, respectively, are the substrate. The level of moisture can also affect the respiration. Commodities with good natural coatings exhibit low respiration.

External Factors

Temperature: Respiration rate of fruits and vegetables increases 2-2.5 times for every 10°C rise in temperature.

Ethylene: In climacteric fruits exogenous application of ethylene advances the respiratory peak. In the non-climacteric fruits, respiration may be stimulated anytime during the life of the detached fruit, and an immediate rise in respiration occurs after ethylene application.

Oxygen and carbon dioxide: Rate of respiration increases with the increasing supply of oxygen, and carbon dioxide has an opposite effect.

Growth regulators: Depending on the time of application and quantity absorbed by the fruits, growth regulators may inhibit or stimulate the rate of respiration.

Fruit injury: Depending on the fruit variety and severity of bruising, injury can stimulate the respiration. This effect is indirectly attributed to ethylene production.

8.5 CLIMACTERIC AND NON-CLIMACTERIC FRUITS AND VEGETABLES

Climacteric fruits show a large increase in respiration rates and ethylene production as they ripen. In contrast non-climacteric fruits exhibit low CO_2 and C_2H_4 evolution rates during ripening. A non-climacteric fruit reacts to ethylene treatment at any stage of its pre-harvest or post-harvest life, whereas a climacteric fruit exhibit a respiratory response only if ethylene is applied during the pre- climacteric stage, and it becomes insensitive to ethylene treatment after the onset of the climacteric rise Table 8.1.

Table 8.1: Some Examples of climacteric and non-climacteric fruits and vegetables

Climacteric	Non-climacteric
Apricot, banana, mango, avocado, cherry, peach, plum, pear, cabbage, carrot, tomato, pepper Apple, garlic, onion	Strawberry, blackberry, cauliflower, citrus, lima beans, Snap beans, Brussels sprout, grape, cucumber, pomegranate

8.6 MORPHOLOGICAL AND CHEMICAL CHANGES DURING RIPENING AND SENESCENCE

Compositional changes take place in harvested fruits and vegetables, which influence their colour, firmness, taste and aroma. During ripening there is change in colour of many products as the chlorophyll breakdown takes place, and new pigments are synthesized. Changes in carbohydrates include starch to sugar conversion and vice-versa, breakdown of pectins and other polysaccharides, which results in softening of fruit. Changes in organic acids and lipids influence flavour development. Synthesis of volatile organic compounds during ripening emits typical aroma of the commodity.

Many structural changes occur during ripening and senescence. In the sequence of events that leads to senescence of plant cell decrease in ribosome population and chloroplast breakdown are the first detectable symptoms.

Ribosomes

No change in ribosome population during maturation and ripening of tomato was observed as they were distributed throughout the cytoplasm and along the rough endoplasmic reticulum at all stages of fruit development, although a decrease was observed in post climacteric stage.

Mitochondria

A general degradative process is characterized by the reduction in the number of intact mitochondria, as senescence can be termed as the failure of the system responsible for keeping the cells in good repair. In the final stage of senescence, a shortage of ATP resulting from fewer active mitochondria can cause a loss of membrane integrity and redistribution of enzymes and substrate. In general mitochondria appears to be more resistant to breakdown than other organelles, and they persist till late stages of senescence.

Cell Wall

Differences occur in cell wall structure at different stages of fruit development. Loosening of cellulosic fibrillar structure is seen during ripening depending on the degree of solubilization of pectic and hemicellulosic substances between the microfibrils. Thickness of cell wall changes and cells turn round and tend to dissociate.

Plastids

Plastids show more striking changes than all other organelles. As fruit matures, starch granules disappear and the osmophilic granules increase in number and size. With maturity grana disappear and structure similar to thylakoid plexes are seen. In ripe stage, chromoplast development takes place with granal lyses and increase in size and/or number of lipid granules. Generally chlorophyll disappears from senescing plant tissue with degeneration of granal lamellae, formation of a single membrane system, and an increase in size and/or osmiophilic globules.

Intracellular Spaces

Intracellular spaces are formed by separation of cells along the middle lamella. A decrease in porosity is observed with ripening.

Other Cell Organelles

The endoplasmic reticulum vesiculates and disappears with senescence. Golgi apparatus also disappears and tonoplast breakdowns with senescence. The nucleus and plasmalemma are the last structure to vanish and it brings about the death of cell.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How developmental stages affect the respiration rate of the product?

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2. How chemical changes taking place during ripening affect rate of respiration?

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3. What changes in mitochondria occur during ripening and senescence of the produce?

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4. What are the cell wall changes during ripening and senescence of the produce?

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8.7 LET US SUM UP

Taste of fruits and vegetables is associated with the amount and type of chemical constituents and the physical nature of the commodity at harvest. During ripening a series of changes in colour, texture and flavour are evident. These changes are influence by respiration and ethylene production by the produce. It is important to realize that no improvement in quality can be done in post harvest stage; only efforts can be made to keep intact the quality attained at harvest.

8.8 KEY WORDS

Physiology : Study of the functions and vital processes of living plants.

Ethylene : A colourless flammable gas which stimulates ripening.

Ripening : The advance stage in the development at which fruit and vegetable are suitable for consumption/ utilization.

Climacteric : Fruits/vegetables showing a sudden upsurge in respiration coupled with ethylene evolution.

Non-climacteric : Fruits/vegetables who do not show a sudden upsurge in respiration coupled with ethylene evolution.

Respiration : Process of inhaling oxygen and exhaling carbon-di-oxide.

Development : A process of growth towards more perfect stage.

Maturation : Becoming full grown or fully developed.

Senescence : Beginning of final phase in the life of plant.

Volatiles : A substance having the quality of gas.

Pigments : Colouring matter in the cells or tissue of fruits and vegetables.

Aroma : A smell coming out of the product.

Fermentation : The breaking down of complex organic compound by microorganisms.

Coating : Layering of the outer surface of fruits or vegetables.

Bruising : To injure the surface without breaking the skin, but causing Discoloration.

8.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:
   - Pectic substances
   - Starch
2. Your answers should include following points:
   - Chloroplast
   - Chromoplast
   - Mevalonic acid
   - Chlorophyllase
3. Your answers should include following points:
   - Starch
   - Acids
4. Your answers should include following points:
   - Insoluble carbohydrates
   - Gradient

Check Your Progress Exercise 2

1. Your answers should include following points:
   - Fruit size
   - Size and metabolic stage of tissues
2. Your answers should include following points:
   - Sugars
   - Organic acid
   - Lipoids
3. Your answers should include following points:
   - More resistant
   - Membrane integrity
4. Your answers should include following points:
   - Cellulosic fibrillar
   - Pectin solubilization

8.10 SOME USEFUL BOOKS

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UNIT 9 PHYSIOLOGICAL DISORDERS

Structure

9.0 OBJECTIVES

After going through this unit, you should be able to:

- know the reason for different physiological disorders;
- mention the symptoms of major physiological disorders;
- state the importance of minerals in fruit quality; and
- tell how the occurrence of physiological disorders can be avoided.

9.1 INTRODUCTION

Physiological disorders are related to exposure of undesirable environmental condition such as temperature, very low oxygen or high carbon dioxide, humidity and nutritional disorders etc. In general any breakdown of tissues other than invasion of pathogens or mechanical damage is termed as physiological disorder.

Different fruits and vegetables have different tolerance limits to cold (low) temperature, storage below which the stored commodity is susceptible to various kinds of disorders including fungal infections.

9.2 PHYSIOLOGICAL DISORDER OF TROPICAL AND SUB-TROPICAL PRODUCE

Many tropical and sub-tropical varieties of fruits and vegetables when stored below 10°C for a longer time suffer physical and physiological injuries. These injuries are of the following types:

i) Superficial scald
ii) Carbon dioxide injury
iii) Core flush

iv) Breakdown of the flesh of the stored commodity:
  a) Low temperature breakdown [LTB]
  b) Senescent breakdown
v) Water core
vi) Bitter pit
vii) Freezing injury
viii) Chilling injury

1. Superficial scald

The common feature of this is that the areas of the skin of the stored commodity turn brown. These areas are very slightly sunken and the lenticels look as injured spots, e.g. apples, pears, and peaches.

2. Carbon dioxide injury

Usually occurs in CA storage when carbon dioxide concentration goes higher. The periphery of the internal tissue turns slightly brown initially and as the time of exposure to CO_2 prolongs the tissue turns deep brown, e.g. apples, pears, mangoes.

3. Core flush

Core flush is yellowish-pinkish discolouration of the core of the apples. It may appear as a ring of damaged tissue or it may involve the whole area of the core.

The incidence of the core flush is aggravated by increased CO2 concentrations in the core atmosphere. Storage in the absence of CO2 and in low concentration of oxygen gives good control of core flush.

4. Low temperature breakdown [LTB]

Low temperature breakdown of apple is seen in the cortical tissue as a general browning of the flesh that can vary in intensity from season to season.

As the disorder progresses the skin becomes discoloured and water logged, giving a dark translucent appearance. The cut surface looks moist.

5. Senescent breakdown

Senescent breakdown of apples and pears is a disorder associated with over maturity and it develops further at high temperatures when the fruit is removed from store. It is variable in appearance but fruit looks drier as compared to low temperature breakdown. Sometimes the flesh also becomes mealy.

6. Water core

Water core is a condition in which parts of the flesh of the commodity appear to be translucent and glossy because the intercellular spaces have become injected with the sap. It is more prominent in the flesh and may also appear near to the surface of the skin. Water core disappears rapidly at higher storage temperatures, but badly affected fruits cannot recover from water core disorder.

7. **Bitter pit**

Bitter pit is appearance of small brown dry areas on the skin, which also disfigures the flesh. The location of the pit is usually below the skin, but in severe cases the pits may extend right up to the cortex. Under the microscope the pitted areas are seen to consist of dead collapsed cells. Deficiency of calcium in the soil causes bitter pits, and it can be avoided by pre-harvest spray of calcium. The bitter pit mainly occurs in pears, apples, and guavas.

8. **Freezing injury**

Freezing injury occurs when storage temperature falls below 0°C. The affected fruit externally has an irregular shape caused by tissue collapse, and the juice streams out of the injured or cut tissue even under slight pressure.

In apples, freezing injury characteristically occurs in cone-shaped segments with the apex at the core.

9.3 LOW TEMPERATURE DISORDER – CHILLING INJURY

Chilling injury is a major problem in post harvest handling of fruits and vegetables. This injury occurs at temperatures which are lower, but much above the freezing point of the tissues. Chilling injury is manifested in a variety of symptoms such as surface pitting, discolouration, appearance of water soaked areas, increased susceptibility to decay, loss of sprouting ability, etc. Some of the important physiological responses to chilling injury are stimulation of ethylene production, and failure of colour development.

Chilling injury is a phenomenon during which many tropical and subtropical fruits and vegetables when stored below 10°C develop the symptoms of skin discolouration and browning, pitting of the skin, water soaked spots, soggy flesh and failure to ripen when the commodity is removed to room temperature [RT].

The chilling injury symptoms are visible only after 2 or 3 days storage at room temperature.

9.3.1 Control of Chilling Injury

Temperature Pre-conditioning

Gradual reduction of storage temperature of the cold room is found beneficial in alleviation of CI. Pitting in stored banana was found reduced from 90.6 to 8.9% when stored at 13°C-12°C-11°C-10°C at 4 days intervals.

Regulating Humidity

Storage humidity at 95-100% was found to reduce CI symptoms in bananas stored at 11°C when they are covered in polythene bags.

Intermittent Warming

Intermittent warming [IW] of the commodity for every 5 days at low temperature/2 days at Room Temperature was found effective to control CI. Raw green mature papaya stored at 7°C for 5 days when transferred and kept for 2 days at RT did not exhibit CI symptoms for 3 weeks storage. Similarly, green mature bananas responded to this treatment with control of CI symptoms when removed to RT after 3 weeks I.W. at 8°C.

Wax Coatings

Suitable concentrations of wax coatings of the skin of papaya, banana and mango stored at 8°C for 2 weeks did not develop CI symptoms when removed to RT.

Modified Atmosphere Storage [MA Storage]

When the fresh commodity is enclosed in the thin low density polyethylene (LDPE) bags and stored at chilling temperature, the commodity stored, resisted CI up to 2 weeks. Banana, papaya and mango when enclosed in sealed polythene bags develop modified atmosphere and humidity inside the bag, which helps to alleviate CI symptoms. The fruits when removed to RT after 2 weeks of storage at chilling temperature and 8°C did not show CI symptoms.

9.3.2 Chilling Injury Symptoms

Fruit	Safe storage temperature (°C)	Symptoms
Banana	12	Brown streaking on screen
Cucumber	7	Dark coloured water soaked areas
Brinjal	7	Surface scald
Lemon	10	Pitting, red blotches, membrane staining
Mango	12	Dull skin, brown areas on skin
Papaya	7	Pitting, water soaked areas
Pineapple	10	Brown or black flesh
Tomato	12	Pitting

9.4 HIGH TEMPERATURE DISORDERS

Exposure to high temperature or direct sunlight can cause bleaching, scalding, uneven ripening and desiccation in horticultural produce. Sunburn scald in apple is an example of high temperature disorders and its symptoms vary from brown to black areas damaged by sunlight.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is chilling injury?

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2. What are the symptoms of chilling injury in lemon and mango?

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3. What are the general symptoms of high temperature disorders?

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4. What is sunburn scald of apple?

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9.5 DISORDERS DUE TO ALTERED ATMOSPHERIC COMPOSITION

Although modification of atmosphere around produce is done to extend the shelf life of horticultural commodity, they are very sensitive with regards to the concentration of carbon-di-oxide and oxygen. High carbon-di-oxide levels cause uneven colour development and excessive softening in tomatoes. Reduced oxygen levels cause internal browning of pears. Some physiological disorders of fruits are shown in Table 9.1.

Table 9.1: Physiological disorders of fruits

Product	Disorder	Symptoms
Apple	Superficial scald	Sunken skin discolouration
	Sunburn scald	Brown to black area damaged by sunlight
	Senescent breakdown	Brown, mealy flesh
	Low temperature breakdown	Browning in cortex
	Water core	Translucent areas in flesh
	Brown heart	Brown areas in flesh
Pear	Core breakdown	Brown, mushy core
	Neck breakdown	Brown to black discolouration of vascular tissues connecting stem to core
	Superficial scald	Grey to brown skin speckles
	Brown heart	Brown areas in flesh
Grape	Storage scald	Brown skin discolouration
Citrus	Storage spot	Brown sunken spots on skin
	Cold scald	Superficial grey to brown patches
	Stem end browning	Browning of shrivelled area near stem end
Peach	Wooliness	Red to brown dry areas in flesh

9.6 MINERAL DEFICIENCY DISORDERS

Plants require a balanced mineral intake for proper development; if any of the essential minerals are deficient it will be manifested during plant development or in the plant or plant parts. Many times the browning symptoms in certain fruits and vegetables are attributed to the deficiency in some mineral constituents of the produce. These disorders can be prevented by either pre-harvest or post harvest application of specified minerals.

Calcium deficiency is one of the major problems. Calcium is physiologically important mineral as its deficiency may suppress respiration and several other metabolic sequences in plant tissues. Further, calcium is associated with pectic substances in the plant cell that helps in strengthening of tissue. Potassium is other mineral that manifests its symptom both during excessive application and deficiency. Other minerals may also play role in maintaining proper plant and produce health. Toxicity of copper, iron and cobalt may cause similar symptoms to low temperature break down and superficial scald in apples. Copper also acts as a catalyst to browning enzymes (Table 9.2).

Table 9.2: Mineral deficiency disorders in fruits and vegetables

Fruit	Mineral	Disorder
Apple	Calcium	Bitter pit, cork spot, cracking, low temperature break down, senescent breakdown, water core
	Boron	Internal cork
	Potassium (High)	Bitter pit
Beans	Calcium	Hypocotyls necrosis
Cabbage	Calcium	Internal tipburn
Carrot	Calcium	Cavity spot, cracking
Mango	Calcium	Soft nose
Pear	Calcium	Cork spot
Pepper	Calcium	Blossom end rot
Potato	Calcium	Tipburn
Tomato	Calcium	Blossom end rot, cracking, black seed
	Potassium	Uneven ripening

Blotchy Ripening, Greenback or Solar Yellowing of Tomatoes

It is green, yellow or translucent hard patches of tissue spread over the red colour of ripe tomatoes. The parenchyma surrounding the vascular bundles of the outer fruit walls are necrotic and disorganized. The affected tissues may either be opaque or brownish in colour and are lignified and starchy.

The green areas of blotchy fruit contain less solids, nitrogenous compounds and sugars; more total and insoluble pectic substances; less pectinesterase and polygalacturonase activity; and lower titratable and total acids than the red parts.

Blotchy ripening of fruit may be affected by the nutrition of the plant. Potassium deficiency or excess nitrogen nutrition may bring about more blotchy fruits. Blotchy fruit may be not only a nutritional effect but also a result of stress leading to tissue compartmentalization. The blotchy section has different metabolic pattern than the normal tissue development.

Shading fruit with aluminium foil caused a decrease in the severity of greenback, whereas shading with black PVC foil increased its occurrence. Green back is caused by variations of temperature on the tomato fruit pericarp during maturation. The higher the temperature at any part of the fruit, the greater the incidence of greenback. Temperature is a direct effect of incoming radiation and heat transfer coefficient. Factors such as variation in the chlorophyll content around the fruit, position of the fruit relative to the sun, stages of maturity, size and variety will produce localized temperature differentials. Metabolic activity would likewise differ, leading to blotchy ripening.

It is commonly observed that large fruits are more frequently and severely damaged by greenback than small fruits. The intensity of greenback depends on length of exposure and degree of temperature. Defective colouration of tomato shoulders is not primarily a heat effect but mainly a result of short-wave radiation. Short-wave radiation not only reduces the carotenoid synthesis in blotchy fruits, but also inhibits the C2H4 production.

Blossom-end Rot

This disorder is described as brown proteinaceous inclusions occurring in the epidermis and pericarp, at the stylar-end of the fruit. Cell membranes become disorganized and tissue necrosis develops underneath, the skin remaining intact. The causal factor for blossom end rot may be the Ca deficiency. This can be effectively reduced by application of Ca $(NO_3)_2$ and gypsum or by spraying with $CaCl_2$ solution. Excess K may also result in the production of blossom-end rot, probably through a Ca deficiency-induced effect. Water stress may aggravate this disorder.

Cuticle Cracks

Shallow, slightly dark, tiny but well healed cracks on tomato fruit surface are referred to as cuticle cracks or skin checks. Because the waxy covering is removed, water loss is rapid and shrivelling and discolouration follow. Cuticle crack is probably caused by the fluctuations in moisture regime and temperature.

Fruit Tumor or Waxy Blister

This disorder consists of a wax-like irregular tumor on the fruit surface starting as smooth, turgid blisters, which turn brown, depressed and cracked as the fruit ripens. Blisters may be induced by rubbing green fruits and storing at 20-35°C. The injury caused by rubbing apparently sparks the synthesis of more growth hormones with kinin like activity, which causes increased cell division and result in tumorous growth. Blister is mainly a handling disorder and may be controlled by careful picking, proper packing and minimizing damage during transport. Ripening at lower temperature is also recommended for avoiding this disorder.

Growth Cracks

This disorder is characterized by rupturing or cracking of the fruit, usually either around the stem-end (concentric) or from the stem-scar down the fruit shoulders (radial). Abundant rainfall and high temperatures favours rapid growth and predispose tomato fruits to growth cracks. The specific cause of rupturing could be an uncoordinated tissue expansion during growth or simply a turgidity phenomenon. It may be controlled by picking before the fruits are ripe and by planting crack-resistant varieties.

Puffiness

Puffy tomato fruits are downgraded or are rendered unmarketable in serious cases. Affected fruit is hollow and light in weight. The surface between the internal cross walls is usually flattened or sunken. The large pockets are observed in cut tomatoes in the cavities occupied by the seed-bearing tissues.

Factors, which inhibit normal pollination, may cause poor development of seed-bearing tissues, and growth in such fruits lags behind the normally developing peel tissues leaving empty spaces between them. A too high or too low growing temperature, drought, excessive moisture supply and heavy N application interferes with normal pollination and hence should be avoided to reduce the incidence of puffy fruits.

Sunscald or Sunburn

Cabbage: Sunscald in cabbage starts as blistered, irregularly shaped areas that become papery and bleached later. Exposed leaves on the top of the head are usually affected. Because of possible secondary infection by decay-causing microorganisms, affected leaves should be removed prior to packing.

Pepper: The sunscald in pepper is due to exposure of the fruit to the intense heat of sunlight. Sunburn appears as light-coloured and soft areas on the fruit surface, which eventually becomes papery. Another type of injury, termed delayed sunscald, which appears after harvesting. Initially the fruit is water soaked and becomes dry and brown, but lacks the bleaching and papery symptoms.

Pomegranate: Exposure to the sun during fruit growth produces a brown, tough, leathery and slightly russetted patch on the rind.

Beans: Beans affected by sunscald appear first as tiny reddish spots forming reddish-brown streaks across the pods. At an advanced stage of sunscalding, pods become water-soaked followed by browning and shrinking of the affected tissue. This occurs only on one side of the pod, and is more serious during moist weather.

High Temperature – Induced Desiccation

Avocado (Heat Injury): Prolonged exposure of some cultivars of avocados to a temperature of 20°C causes damage to the fruit and the fruits held at 25°C to 30°C will not ripen normally. It causes uneven softening and discolouration may occur which makes fruit unpalatable due to off-flavours. The flesh darkens and brown spots appear on the skin. At 32°C, the flesh becomes rubbery and pitting like symptoms on the skin may occur.

Banana (Dehydration): Water loss in banana results in shrinkage of tissue or may even cause symptoms similar to severe chilling. Pitting in bananas may be induced either by high temperature or low RH. RH below 80% may produce symptoms characteristic of low-temperature breakdown. These effects lead to abnormal ripening. Therefore to avoid dehydration, bananas should be promptly cooled after harvesting and stored at humidities between 90 and 95%.

Lychees (Browning): Lychee browning is a desiccation phenomenon due to exposure to dry air. It starts at tubercle tips, creeping downward and spreading on the bright-red shell. At an advanced stage, the entire surface of the fruit may turn completely brown. Browning may be reduced by storing at 2°C for up to 5 wk or at 7°C for less than 2 wk in polyethylene bags.

Onions (Translucent Scales): Translucent scale of onions consists of clearing of the normally opaque cells due to a disintegration of the parenchyma walls. It looks similar to freezing injury, however the distinguishing features are mentioned below:

	Freezing Injury	**Translucent Scale**
Pattern of damage	From the surface inward	No pattern
Stem plate	May be affected	Not affected
Scales	Outer more affected than inner	Inner may be more affected than outer
Freshly cut surface	Dry	Moist
Areas of white opaque tissues	Present	Lacking
Epidermis of affected scales	Loose	Loose only in severe cases
Texture of surface with epidermis removed	Grainy, rough	Smooth, slick

Major factors influencing the severity of this disorder include delays at 15 to 30 days between the end of curing and the start of storage at 0°C during 7 months storage. Tropical conditions where the temperatures goes above 32°C for about 50% of the growing period or above 35°C for about 30% of growth period of the plant, have high probability of developing this disorder during storage. Prompt cold storage and early covering the bulbs with soil reduces the incidence.

Growth Cracks and Splitting

Pomegranate (Splitting): Cracking of pomegranate during ripening is a natural characteristic believed to be due to humidity fluctuations, dry winds and irrigation. Picking over-mature fruit should be avoided to prevent cracking during storage. Cracked fruit may serve as an avenue for entrance of decay-causing organisms

Sweet potatoes (Growth cracks): Fairly deep fissures may develop on sweet potatoes due to successive growth interruptions in the field. In some cultivars, high N fertilization and irrigation followed by a dry weather may induce growth cracks.

Disorders Related to Certain Field Conditions

Carrots (Scab Spot complex): Early signs of scab spots of carrots are pockets of black necrotic tissues occurring usually at or near the lateral rootlets, which later become sunken and scab-like. The cause of this disorder could be related to nutritional, climatic and genetic factors.

Potatoes (Surface Browning): Under conditions of low RH and high harvest temperatures, some portions of mechanically injured tubers undergo oxidation, resulting in objectionable surface browning. The affected area darkens with time and becomes much more noticeable after a few days. Surface browning may be induced at RH ranging from 25 to 30%. Temperature is secondary to RH as a factor in browning, but higher temperatures are associated with low RH, thus compounding the predisposition of tubers to oxidation.

Mango (Black-tip): Orchards near the brick kiln suffer heavily every year due to black tip necrosis of mango. Small-etiolated area at distal-end of the fruit appears after 3 to 4 days of fruit setting. It gradually increases in size and the tip becomes necrotic, often exposing the stone of the fruit as a result of disintegration of outer tissues. Affected fruits do not mature properly and tip becomes hard and black.

Regular sprays of boron from the flowering stage can control this disorder. Spraying mango tree with aqueous solutions of NaOH and Na_2 CO_3 minimizes losses due to black-tip.

Pineapple (Endogenous brown spot or black heart): This physiological disorder in its early stages is characterized by the formation of watery spots at the base of fruit lets near the fruit core. With increase in severity of the disease, the spots enlarge and turn brown; with further increase in severity, the spots turn darker and may join together to form a dark mass in the centre of the fruit.

It can develop in the fruit if the pineapples are chilled at low temperatures. There are no visible symptoms of the disease in uncut fruit either before or after the onset of the spots in the pulp, thus making it impossible to remove affected, fresh fruit prior to shipment. Hence, losses in commercial surface shipments of refrigerated fruit have been high, but no losses occur in non-refrigerated air shipments.

Storage Disorders

Onions and other commodities (Ammonia injury) Accidental exposure of onions to ammonia during cold storage may bring about marked discolouration. Red onions change to blackish-green and then dull greenish-black later. Yellow onions show initial yellowish-green colour on the edges of scales, turning bronze to brownish-black at an advanced stage. White onions become greenish-yellow on exposure to ammonia. Discolouration is always much more rapid and pronounced in a more humid atmosphere. Exposure to a 1% ammonia vapour for one hour is sufficient to initiate discolouration. Exposure to higher concentration of ammonia from leaks in cold storage may bring about colour changes almost immediately, and brownish-black areas may be seen within a few minutes.

Other Fruits and Vegetables are also Injured by Exposure to Ammonia

Banana	-	brown to black and tissue breakdown;
Grapes	-	discolouration of berry and complete breakdown of the tissue;
Citrus (sweet orange and lime)	-	dark brown discolouration of the rind;
Mango	-	brown surface, pitting and breakdown of the tissue;
Potato	-	brown to dark brown pock marks, pitting, internal discolouration and watery breakdown
Tomato	-	impaired colour development, discolouration of the skin and breakdown of the tissue.

Potatoes (Greening): Greening of potatoes exposed to light during storage occurs due to synthesis of bitter, toxic alkaloid solanine. Although chlorophyll formation is independent of solanine synthesis the same factors, i.e., light quality and intensity, storage duration and age of tuber, affect solanine formation.

Sweet potatoes (Internal breakdown): Internal breakdown is a storage disorder where the internal tissues of sweet potatoes are pithy, dry and spongy. This usually occurs late in the storage season in warm and dry storage rooms, or in rooms with chilling temperatures.

CA Storage Disorders

Two types of disorder may be developed under a CA storage condition: injury due to sub oxidation and that due to CO_2 accumulation. Other volatiles may accumulate in the storage rooms above the critical level resulting in the development of off-flavours and off-odours and progressive death of the tissue.

Sub-oxidation causes blackheart in potatoes, promotes browning in limes, or produces off-flavour and objectionable alcoholic odour in many fruits and vegetables. High CO_2 on the other hand, (a) produces a slight carbonated taste in melons; (b) a general browning of surface (e.g. asparagus) and internal tissue (e.g. cabbage); (c) a stimulation of ethyl acetate production on strawberries (d) off-flavour; (e) off-odour; (f) pitting; (g) impaired ripening; (h) susceptibility to decay-causing microorganisms; and (i) mild necrosis in some fruits and vegetables.

Disorders of Uncertain Causes

Escarole (Marginal browning)

Edges of leaf blade become dry, dark, curly and brittle. The control measures include refrigerated transit, adequate refrigeration, prompt pre-cooling and marketing, removal of old leaves and discarding over-mature escarole may minimize the occurrence of marginal browning

Garlic (Waxy breakdown)

Garlic bulbs are seriously affected by a yellow waxy breakdown believed to be a physiological disorder. The flesh of the clove is somewhat sticky or waxy to the touch but not disintegrated. The outer scales show no indications of breakdown.

Lettuce (Marginal browning: Pink rib and russet spotting complex)

Marginal browning is a physiological disorder characterized by yellowing, followed by browning or necrosis of wrapper-leaf margins. Adverse growing conditions or improper transit and storage conditions, which accelerate senescence, appear to be the origin of this disease. Control measures include refrigerated transit, adequate refrigeration, prompt pre-cooling and marketing, removal of old leaves and discarding over-mature lettuce may minimize the occurrence of marginal browning.

Heads of lettuce affected by pink rib have pinkish, wrinkled and pebbly textured midribs. Over-mature lettuce or plants held long in storage show higher incidence of pink rib. The causative factor is not known. The control measure includes the measures adopted to delay senescence.

Russet spotting complex includes several types of discolouration originating from the field, transit and storage, but distinction among them is uncertain. These symptoms include russet, vein browning, C_2H_4 burn, red heart, internal browning, brown spot, brown blight, rust or storage breakdown. In general, the variable symptoms are irregularly shaped specks ranging in colour from light yellow, pink to dark brown, affecting the ribs, veins and interveinlet tissues. Because of the complexity of origin, only routine quality control measures may help to ameliorate the disorder. Thus, harvesting properly matured heads, rigid grading and culling at handling points, use of refrigerated trucks during transport and prompt pre-cooling and marketing may reduce its incidence.

Mango (Internal breakdown): This physiological disorder is most common in ‘Alphonso’ mango. It is termed as ‘internal breakdown’, ‘spongy tissue’, or ‘soft centre’. So far it is observed only in this cultivar. Externally, the fruit appears to be sound. The disorder is noticed when the fruit is cut into halves. It is observed only in semi-ripe and ripe fruits. The breakdown tissue is characterized by pale yellow colour, soft or spongy texture with or without off-flavour. It starts from the tissue adhering to the stone and gradually spreads to the periphery. In extreme cases, the whole flesh portion becomes too soft resembling bacterial rot. The causative factors for the onset of this breakdown and its control are not known.

Pomegranate (Internal breakdown): Internal Breakdown of pomegranate is characterized by arils, which become light in colour; flat in taste; and sticky in appearance. White lines radiate in all directions from the seed to the outer wall or aril.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. How high carbon dioxide and low oxygen are detrimental to fruits and vegetables?

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2. Explain the importance of minerals in quality of horticultural produce?

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3. Explain the role of calcium in avoiding certain physiological disorders.

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4. How copper is helpful in maintaining quality of produce?

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9.7 LET US SUM UP

Different advance techniques are used during production as well as storage of products. It is important to use these techniques properly so that spoilage of product due to physiological disorders can be avoided. Preventing the metabolic sequences that leads to the development of disorder can prevent disorders. Sometimes chemicals are used to prevent the disorders. Genetic improvement of horticultural cultivars may also help in alleviating the occurrence of disorder. Physical methods of maintaining optimum storage temperature and storage atmosphere may help in reducing many disorders.

9.8 KEY WORDS

Disorders	:	Not a normal growth or product.
Symptoms	:	The condition that accompanies something and indicates its existence.
Nutritional	:	Substances that promote growth.
Ethylene	:	A colourless flammable gas which stimulates ripening.
Browning	:	To become dark or surface develops brown pigments.
Deficiency	:	Absence of some essential thing forms the nutrition.
Toxicity	:	Consumption of which acts as a poison.
Genetic improvement	:	Improvement of quality of a product by using the improved hereditary material.

9.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answers should include following points:

   - Low temperature storage
   - Surface pitting
   - Ethylene production
   - Uneven ripening

2. Your answers should include following points:

   - Pitting
   - Dull skin
   - Skin discolouration

3. Your answers should include following points:

   - Bleaching
   - Scalding
   - Desiccation

4. Your answers should include following points:

   - High temperature disorder
   - Sun scorching

Check Your Progress Exercise 2

1. Your answers should include following points:

   - Softening
   - Improper colour development

2. Your answers should include following points:

   - Proper development
   - Deficiency manifested in form of disorders

3. Your answers should include following points:

   - Pectic substances
   - Deficiency suppresses respiration

4. Your answers should include following points

   - Catalyst
   - Deficiency causes disorder

9.10 SOME USEFUL BOOKS

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UNIT 10 FERMENTATION, METHOD OF FERMENTATION AND INDUSTRIAL SIGNIFICANCE

Structure

10.0 OBJECTIVES

After studying this unit, you should be able to:

- state the meaning of biotechnology and fermentation;
- infer the historical importance of different varieties of fermented foods prepared all over the world from various agricultural commodities;
- know the nutritional significance and beneficiary effects of fermented foods and their classification;
- describe the general methods in fermentations for the cultivation of microorganisms;
- state the importance of aerobic and anaerobic fermentations; and
- discuss the difference between solid state fermentation and submerged fermentation.

10.1 INTRODUCTION

In recent years, biotechnology and information technology have been given much importance. It is believed that these areas of Science and Technology would help to improve the standard of living as well as the life span all over the world. Biotechnology is the integrated use of biochemistry, microbiology and chemical engineering to achieve industrial application of microorganisms and tissue culture. Unlike material sciences, in biotechnology the key of any process or activity is the biological source viz., microorganisms (bacteria, yeasts, fungi and virus) plants and animals. If we scan the books and journals, we find most of the processes are based on microbes through fermentation. These microorganisms produce newer types of products (vitamins, antibiotics, hormones, amino acids, enzymes, beverages, fuels and solvents, life saving drugs) or convert raw food stuffs (cereals, pulses, fruits, vegetables, animal, fish, poultry and dairy products) into palatable, nutritious and processed foods with longer shelf life.

Fermentation is the oldest word used for biotechnology from time immemorial when nothing was known about microorganisms or technology. Bread-making, cheese manufacture and production of wine and alcoholic beverages are the certain examples. *Fermentation can be defined as the chemical modification of organic compounds or raw materials or agricultural commodities with the aid of enzymes produced by microorganisms*. With respect to foods, it is the transformation of physical structure and chemical constituents (carbohydrate, proteins, fats and nucleic acids) by microorganisms and their enzymes under aerobic (presence of oxygen) or anaerobic (absence of oxygen) conditions. Examples are wine from grapes, cider from apples, beer from malted barley, whisky, gin, rum, pickles, curds, idli and dosai, bread and nan, cheese and lactic beverages.

10.2 HISTORY OF FOOD FERMENTATIONS

When we go through several books and research articles we find a number of definitions of fermentation. The most frequently used names were: respiration, fermentation, putrefaction, decay, digestion, dissimilation and ferment. However, the major developments in the twentieth century in the field of microbiology, molecular biology, chemical engineering and biochemical engineering and biochemistry have resolved this confusion.

If we look at the human's civilization, the man has passed through several stages viz., hunting, gathering food to this stage of collective cultivation and processing of foods. During the early stages, sun-drying, salting and fermentation were practiced and in certain pockets especially in tribals and rural areas in India and other countries, these are in vogue sometimes singly or in combinations.

The Egyptians, Sumarians, Babylonians, Assyrians and Indians knew the technique of alcoholic beverages production. Indians were used to *Ashwas* and *Arishtas*. Drinking wine was common in the Roman Empire throughout Europe and North Africa. Mead was prepared from honey. Idli, dosai and other fermented foods were introduced in South Indian dietary system since time immemorial. Soy sauce, miso and tempeh were known to Chinese as early as 1000 BC and the techniques were passed on to Japan around 600 AD. Fermented dairy products such as curds and butter milk are referred in early Sanskrit literature. The word fermentation comes from the Latin word *ferveo* meaning to boil. From this *fermentum* was derived which means yeast or leaven. The evolution of bubbles due to carbon dioxide production was noticed in alcoholic fermentation and hence this name was given. Louis Pasteur in France in 1861 was first to declare that a group of microorganisms viz., yeasts are responsible for fruits and grains fermentation for the manufacture of wine and beer. He also described that along with desirable type of microorganisms, undesirable types also grew in the ferment and also these were responsible to spoil the quality of final product. He was first to suggest heating at $62.8^{o}C$ for

30 minutes (pasteurization) to eliminate the undesirable microorganisms from the fruit juice before fermentation.

10.3 MICROBIOLOGY AND BIOCHEMISTRY

As you have become aware, food fermentations started with the development of man's civilization purely due to necessity. During those days nothing was known about science and technology of fermentation and also causitive agents viz., microorganisms and their enzymes responsible for it. It was also not known that these microorganisms fall under two categories: **useful** producing life saving drugs, chemicals and fermented foods and products and **harmful** causing spoilage of the products and responsible for many deadly diseases (Cholera, typhoid, plague, small pox etc.). These became evident after the discovery of microorganisms and their systematic scientific studies in the middle of nineteenth century when Louis Pasteur established their role in fermentations and human and animal diseases. In India, food prepared if left over night outside, gets spoiled due to the growth of microorganisms. Microorganisms spoil the food by damaging the structure, colour, and chemical and physical characteristics both in raw as well as processed foods. Bread (*Rhizopus nigricans, Aspergillus niger, Penicillium notatum)* fresh fruits and vegetables (*Rhizopus* and *Erwinia)* Pickles (*Rhodotorula, Candida, Pichia),* meat (*Alcaligenes, Clostridium, Proteus vulgaris, Pseudomonas fluorescens),* fish (*Flavobacterium, Alcaligenes)* eggs (*Pseudomonas fluorescens)*, orange juice (*Lactobacillus, Leuconostoc, Alcaligenes)* and poultry (*Pseudomonas, Alcaligenes)* are spoiled by a number of microorganisms and thus become unfit for consumption.

Some bacteria such as *Salmonella* spp., *Shigella dysenteriae, Vibrio cholerae, Clostridium botulinum, Clostridium perfringens, Listeria* spp. and *Campylobacter* spp. produce toxins causing food poisoning. *Aspergillus flavus, Pencilllium citrinum, Fusarium graminarium* and many strains and species of fungi in under humid and hot conditions grow on agricultural commodities and food materials and produce different types of toxins which are deleterious to human and animal health.

The growth and activity of microorganisms thus are important in controlling the quality and safety of food. Both harmful and useful microorganisms grow in their environmental and ecological conditions in food commodities, food preparations and processed foods and other systems and produce enzymes, metabolites and toxins depending on nutritional and physical factors. These factors are water activity, pH, temperature, chemical constituents and the buffering compounds. In natural fermentation (without addition of microorganisms, inoculum or starter culture) and controlled fermentation (addition of starter culture/s), microorganisms bring about many chemical and structural changes in organic constituents of foods and thus check the growth of pathogenic microorganisms. Examples are lactic acid producing bacteria, alcoholic fermentations, oxidation of alcohol to acetic acid, production of other organic acids and amino acids and nucleotides and changes in cellulose, hemicellulose, pectins, gums, fats and proteins.

Lactic acid producting bacteria have been used since time immemorial all over the world in preserving and modifying foods such as cereals (idli, dosai, nan) milk (curds), cheeses and fermented meat and fish.

The lactic acid bacteria convert available carbohydrate to lactic acid where by lowering the pH and changing the conditions suitable for the growth of yeast. Some times propionic acid is also produced which acts as a preservative. They also produce flavour compounds e.g. diacetyl, acetaldehyde and acetoin. This action of lactic acid producing bacteria is observed in the production of many traditional and indigenous foods from fruits and vegetables, legumes, cereals, milk, meat, poultry and fish etc. The acids developed by the organisms during the processing of foods contribute to the flavour of the final product and also act as preservatives preventing the growth of undesirable pathogenic and spoilage microorganisms.

Some of these lactic acid producing bacteria produce lactic acid only or acetic acid, formic acid and ethyl alcohol. The organisms producing only lactic acid are known as *homofermentative* and those producing lactic acid with other compounds are *heterofermentative*. Lactic bacteria normally isolated from vegetable fermentations are: *Lactobacillus plantarum, Lactobacillus brevis, Pediococcus cerevisiae, Leuconostoc mesenteroides* and *Lactococcus lactis.*

10.4 NUTRITIONAL VALUES OF FERMENTED FOODS

It is clear now that early man or our ancestors used to store fruits, vegetables, seeds, cereals and even fish and meat for the lean period when the supply of these commodities were scarce. The first reason was storage in order to check the spoilage. The other reason was to improve the nutritional quality and also palatability and acceptability. Certain flavours such as sweet, sour, alcoholic, meat like are obtained in the final fermented products through microorganisms by fermentation. Soybeans and many legumes are difficult to digest and therefore many fermented products are prepared in the oriental countries e.g., China, Japan, Indonesia and African Countries. Besides flavours, these fermentation also increase the levels of vitamins and also amino acids. In general the important beneficial changes obtained through fermentation are:

- Improvement in the profile of flavours, aromas and textures in food substrates.
- Preservation through lactic acid, alcohol, acetic acid and alkaline fermentations.
- Enrichment with essential amino acids, essential fatty acids and vitamins.
- Detoxification of certain toxic constituents during food fermentations.

10.5 NUTRITIONAL QUALITY OF FERMENTED VEGETABLES AND FRUITS

When we consider this aspect of fermentation, most of the vegetables e.g., cabbage (Sauerkrauts and Korean Kimchi), cucumber, green olives, carrots, onion and various others (tomato, pepper, green peas, cauliflower and mustard leaves) are fermented in European countries. Relatively few vegetables are fermented in India. However, the beneficial effect of fruits and vegetables is as follows:

10.5.1 Beneficial Dietary Effects

As reported by nutritionists and health experts, fermented vegetables are rich in fibre, vitamins and minerals. We all are fully aware regarding the importance of fibre in our dietary system. Many intestinal and heart problems are associated with less consumption of fibre especially the processed foods. There are several benefits in consuming fermented vegetables with live lactic acid producing bacteria:

Lactic acid bacteria if taken along with fermented vegetables or fruits in the diet lower the blood serum cholesterol level.

These bacteria produce a number of metabolites which are beneficial to human health.

They help in preventing tumor formation in the body due to stimulation of factors responsible for immunity.

Lactic acid producing bacteria inhibit the formation of carcinogenic compounds in the gastrointestinal tract.

They reduce the growth and enzyme production by the intestinal bacteria e.g., enterobacters.

These bacteria and fermented foods if taken as a food, change the microflora by eliminating pathogenic and undesirable organisms in our intestine and colon.

10.5.2 Protection of Vitamin C in Fermented Vegetables

In India, we do not include fermented vegetables in our dietary system. However, in Europe, North America and Korea, cabbage and several other vegetables are fermented and higher levels of vitamin C is found in them due to its synthesis by microorganisms.

10.5.3 Mineral Preservation in Fermented Vegetables

The fermented vegetables in a meal help higher assimilation of iron. Iron bioavailability is better in lactic acid producing bacteria fermented carrots.

10.5.4 Reduction in Nitrate Content

Due to the widespread use of nitrogenous fertilizers, high quantities of nitrates are sometimes found in food products. This nitrate which is harmless as such, is reduced and converted into nitrites which finally gets transformed into highly carcinogenic nitrosamines. During lactic acid fermentation of vegetables, nitrites are converted into NO_2 which goes out as a gas.

10.5.5 Improved digestibility

Many indigestible compounds responsible for gas and flatulence and also sulphur compounds in garlic or onion are broken down to inoccous break down products.

10.6 POSSIBLE HARMFUL EFFECTS

a) A number of amines are formed during the fermentation of cabbage, carrot, pepper and turnip etc., and thus their higher concentrations cause unpleasant flavour to the final product or toxic effect. Ingestion of certain amines can cause headaches, fever and vomiting almost similar to microbiological food poisoning. Histamine, tyramine, putrescine, and cadaverine are normally noticed in the fermented vegetable products.

b) During the fermentation process D(-)lactic acid is also produced depending on the type and number of lactic acid producing bacteria. D(-) form of lactic acid is not assimilated in the body and thus gets eliminated by the kidney in the form of salts which results in the loss of calcium and magnesium. Normally D(-) lactic acid concentration in the fermented vegetables is low without having any adverse effect on the human health. However, care is needed to restrict the quantity in the meals.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain why a knowledge of biotechnology is useful in understanding microorganisms in fermentations.

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2. What do you understand by fermentation?

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3. Highlight the importance of harmful and useful microorganisms in the spoilage and improvement of food quality.

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4. List the beneficial changes in food commodities by fermentations.

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5. What are the attractive nutritional characteristics of fermented fruits and vegetables?

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10.7 CLASSIFICATION OF FERMENTED FOODS

It is important to know about different varieties of fermented foods prepared and consumed all over the world depending upon the agricultural and food raw materials produced in that region. These fermented foods can be classified into the following categories:

i) Fruit and Vegetable products

ii) Beverages (alcoholic and non-alcoholic)

iii) Cereal products

iv) Milk Products

v) Fish Products

vi) Products from Legumes

vii) Meat products

viii) Starch Crop products

i) Fruits and Vegetable Products

You are now fully convinced that the fermentation of food commodities was practiced by the early man and by trial and error many technologies were developed. Vegetables have been preserved throughout the world by fermentation. Examples are cabbage (Sauerkraut, Korean Kimchi), radish, mustard leaf, gherkins and cucumbers, ginger onion, chilli and bambooshoots (Malaysian pickles), carrot, turnips and peppers. In India, relatively very few vegetables are fermented and preserved for consumption. Among fruits, olives are commercially fermented and consumed in European countries as an appetizer.

ii) Beverages (alcoholic and non-alcoholic)

Beverages are produced in large quantities in all regions of the world. We normally find two types of beverages which are common everywhere. The first group comprises of alcoholic beverages in which fermentation plays a major role in contributing the flavour and chemical and physical characteristics of the fermented products. Beer and wine fall under this category. After fermentation further distillation is done and thus a variety of products termed 'spirits' such as whisky, gin, brandy, rum etc., are produced.

The second category of beverages are non-alcoholic e.g., coffee, cocoa and tea. All of them involve fermentation. India is a major producer of tea and coffee. If you look at the worlds map, you find an interesting observation that these are based on the type of agricultural crops cultivated in that particular area depending on the geographical and climatic conditions. The colder countries of Europe including Britain, Scandinavia, Netherlands and Poland consume beer which is manufactured mostly from barley. The southern countries of Europe grow grapes extensively and produce different varieties of wine. These beverages have spread to many countries wherever the European settled e.g. Northern America (The United States of America, Canada), Australia and South Africa. Rice beer in Indian sub-continent, sorghum beer in Africa, sake (rice) in Japan and a variety of alcoholic beverages are produced in different parts of the world. In Europe and North America apples are used for cider production. In warmer climate in Africa, Asia, Oceania (Australia and New Zealand), the Indian subcontinent and South America the sweet liquid sap of palm trees is fermented to wine. In India, it is known as '*Toddy*'. Cashew apple pulp is extensively is used for the preparation of Feni in Goa.

The alcohol content of most of the fermented materials varies between 5-18%. Its concentration is increased in the range of 35-55% by distillation and thus brandy, whisky rum and gin are manufactured. Consumption of excessive amounts of alcoholic beverages leads to intoxification and loss of body control. Therefore it is prohibited in many countries and also many religions of the world.

In contrast to alcoholic beverages, the non-alcoholic beverages most widely consumed throughout the world are coffee, tea and cocoa and these are largely produced in India especially in southern part of the country. The tea leaves are fermented as such by the natural microorganisms. In the case of coffee and cocoa the pulp surrounding the beans are removed by the natural fermentation. This process contributes to the flavour of the final product. Bacteria, yeasts and moulds are involved in the fermentation of these commodities.

iii) Cereal Products

Cereals are the major staple food in every parts of the world. These are wheat, rice and maize. The most popular fermented cereal product is bread which is consumed in every region. It is done by fermenting wheat flour dough with the yeast *Saccharomyces cerevisiae*. Lao-Chao is a fermented rice product of China prepared by natural fermentation containing strains of *Rhizopus oryzae,Rhizopus chinensis* and *Endomycopsis* species etc., Puto of Philippines, Ang-Kak of China, Ragi of Indonesia, Tape-Ketan of Indonesia, Ogi of Nigeria, Injera of Ethopia and Banku of Ghana are produced extensively and consumed regularly in these countries. In India, mixed fermented preparations of rice and pulses and other commodities are idli, dhokla, khaman, papad and jalebies etc., Ambali, bhatura, kulcha and warri are also Indian fermented foods prepared and used in different parts of the country.

iv) Milk Products

Milk products have been included in our diets since time immemorial. In early days, natural fermentation of milk was the best method of preserving milk. Dahi and Chhanchh (butter milk) are important ingredients of every day's meal all over the country. The other products are youghurt, cultured milk acidophilus milk, cheese, Srikhand, Kefir and Kumiss etc., Fermented milk products have therapeutic properties along with their nutritional characteristics, wholesomeness and good flavour and digestibility. These qualities are introduced in the product by a number of lactic acid producing bacteria e.g. *Lactococcus lactis* subsp. *lactis, Lactococcus lactis* sub-sp. *cremoris* (cultured butter milk, sourcream, cottage cheese, other soft and hard cheeses), *Lactococcus lactis* sub-sp. *diacetylactis* (sour cream, butter, cheese, butter milk), *Streptococcus thermophilus* (yoghurt, *Lactobacillus delbrueckii* sub-sp. bulgaricus (yoghurt, kefir, kumiss, bulgarian butter milk), *Lactobacillus acidophilus* (Acidophilus butter milk).

Realising the health giving properties of fermented milk products, different varieties of preparations are being marketed all over the world. These are acid alcohol fermented milk products, high acid fermented products, medium acid fermented products, low acid fermented products and whey based beverages.

v) Fish Products

The fermented fish products are popular in some countries. Philippine fish sauce and Vietnamese Nuoc-mam are prepared by fermenting sardines, shrimps and small sea fish etc., Malaysian budu is consumed as a condiment on rice and as a flavouring ingredient in various dishes. Baloa baloa is a fermented rice shrimp mixture of Phillipine and consumed by most of the people.

vi) Legumes Products

Pulses constitute an important component of diet after cereals in Asian countries, especially in India. In India we consume tur or arhar, black gram, green gram, Bengal gram, lentils and a range of beans. Soybeans is also gaining popularity in India. Legumes are rich in proteins, and also in oil and carbohydrates. Unlike cereals, their digestibility is poor and therefore, they are fermented to different products in oriental countries e.g., China, Japan, Indonesia, Malysia, Thailand and several African Countries. Majority of these pulses and beans contain oligosaccharides such as stachyose and verbascose which cause flatus in the intestine. Trypsin inhibitors are also present in these agricultural commodities. Fermentation stimulates these undesirable constituents. Thus the fermentation improves digestibility, nutritional quality and textural characteristics of the fermented products. Tempeh, sufu, soybean milk, soy sauce, natto, bangkrek, khaman, warries and mixed fermented foods containing cereals and pulses e.g., idli, dosai, dhokla etc., are consumed in different regions of the world.

vii) Meat Products

There are not many fermented meat products. These products are dry and semi-dry sausages. In the United States of America, the commercial sausages are Genoa and Salami. Among the popular European brands (dry) are summer sausage, cervelet, thurunger, and Teewurst. Semi-dry-sausages are turkey sausage, fermented frankfurter and Frischwurst etc., In Europe and Western World, fermented sausages are preferred whereas in India, their consumption is almost negligible. The lactic acid producing bacteria e.g., *Lactobacillus plantarum, L. sake, L. curvatus, Pediococcus acidilactici, P. pentosaceus, Lactococcus lactis* are mainly responsible for fermentation of meat. The safety and shelf life of the products are important because these products are contaminated easily and frequently by pathogenic microorganisms.

viii)Starch Crop Products

Cassava (tapioca) is a major food crop cultivated in several African Countries. It is a staple food to most of the people. It contains cyanogenic glucosides and therefore it must be processed. During fermentation, the cyanide content is reduced completely. Gari, lafun, fufu, peujeum, poi and tape are some of the products. Maize, Sorghum and millets are used for the preparation of fermented products like ogi, uji, koko fube and chika etc.

10.8 GENERAL METHODS OF FERMENTATION

The purpose and importance of food fermentation in our life including food preservation, textural modification and nutritional improvement, has already been highlighted earlier. In recent years, the fermentation industry stands next to information technology (IT) and software industries. It is therefore, pertinent to know general method's used in fermentation for the production of fuels, food and pharmaceutical products and life saving drugs.

There are two distinct types of fermentation which are commonly used for the above-referred purpose. These are:

a) Aerobic fermentation

b) Anaerobic fermentation

Aerobic Fermentation

These are carried out under the aerobic conditions in the presence of oxygen which is required for the growth and product formation by the microorganisms. Majoirty of the fermentations such as antibiotics, single cell protein, enzymes and amino acids come under this category. As listed above, the key of these fermentations is the microorganism/s and raw materials (ingredients) and cultural (pH, temperature, humidity and water content) and nutritional characteristics influence the product formation significantly. In many of the fruit and vegetable and agricultural commodities fermentations, the microorganisms grow at very low moisture level whereas in others contrary to this, it is carried out at very high levels of moisture in the range of 85-90% with adequate supply of oxygen. The former is termed as the solid-state fermentation (SSF) and the latter is called as the submerged culture fermentation.

Solid-State Fermentation (SSF)

SSF refers to the growth of microorganisms on solid materials without the presence of free liquid. It is considered to be economical since low moisture content is used and also does not require expensive equipments e.g, sophisticated fermentors. It is extensively practiced in the oriental food fermentations (miso, tempeh, soysauce, natto), secondary metabolites, enzymes, organic acids and composting etc. Although solid-state fermentation is a simpler and less expensive process of growing microorganisms, recovery of the final product adds finally to the cost during the down stream processing step. However it is widely followed for food and feed enrichment, food and feed enzymes production and composting and waste minimization.

Submerged Culture Fermentation

This method of fermentation has been practised for several years for the production of life saving drugs, enzymes, amino acids and organic acids by bacteria, yeasts, fungi and actinomycetes etc. Oxygen is supplied by either shaking or bubbling air through the liquid medium. Agitation, aeration and temperature affect the fermentation. Batch culture or continuous culture methods are followed for the production of fermented products - commercially.

Anaerobic Fermentation

These are carried out by strict anaerobes or facultative anaerobes such as bacteria and yeasts in the absence of oxygen. Examples of anaerobic fermentation are:

Ethanol (ethylalcohol)	→	*Saccharomyces cerevisiae* *Saccharomyces ellipsoideus*
Brewing (beer)	→	*Saccharomyces carlsbergensis* *Saccharomyces cerevisiae*
Lactic Acid Food preservation and fruit and vegetable fermentation	→	*Leuconostoc mesenteroides* *Pediococcus* spp., *Lactococcus* spp.
Acetone and butanol	→	*Clostridium acetobutylicum* *Clostridium Saccharoaceto butylicum*
Biogas (Methane carbon dioxide and other gases)	→	Strict anaerobic fermentation

10.9 PRE-REQUISITES FOR INDUSTRIAL FERMENTATIONS

After knowing these preliminary information about the fermentations, it is necessary to know what are the important points to be considered before starting laboratory or industrial scale fermentation.

a) Microorganism/s is the key for any fermentation whereas fermentor is the heart of the process. The choice of a good medium/substrate/raw-material is virtually as important as selecting a right type of strain or microorganism for the success of fermentation. The medium serves the following purposes:

i) It supplies nutrients for growth.
ii) It supplies nutrients for energy.
iii) It supplies nutrients for building of cell substance.
iv) It is required for the production of final product.

Nutrients needed for the growth and product formation are:

i) Carbon compounds derived mostly from starch, sugar and molasses.

ii) Nitrogeneous compounds.

iii) Inorganic salts.

iv) Water.

v) Vitamins.

vi) Growth factors.

vii) Precursors of fermentation products.

viii) Dissolved oxygen and other gases.

ix) Buffers.

x) Antifoam substances.

xi) Lysate of dead cells.

b) As you have become familiar that fermentation is a microbiological processes hence a potent strain of fungi; yeasts and bacteria is required for desired results. The choice depends upon many factors, the most important being the nature of the raw material. The youghurt preparation requires a strain of *Lactobacillus delbrueckii* sub sp. *bulgaricus* and *Streptococcus salvarius* subsp. *Thermophilus* and milk whereas *Leuconostoc mesenteroides, Lactobacillus, plantarum* and *Pediococcus cerevisiae* become predominant in cabbage for sauerkraut fermentation. In the mixed natural fermentation, it is not possible to control the number and type of microorganisms. Contrary to this in controlled fermentations such as alcoholic beverages, brewing and life saving drugs, an ideal microorganism is needed having the following characteristics:

i) The strain should grow profusely either in liquid or solid state conditions.
ii) The strain should be a pure culture and free of phages.
iii) The strain can be stored for a long period without any genetic change.
iv) The strain should always produce the predictable amounts of metabolite.
v) The strain should be amenable to strain improvement.

c) In nature, microorganisms exist as a mixed culture system and based on the chemical and physical characteristics of the substrate and environmental factors, one or two organisms dominate and thus desired fermentation is achieved. But in monoculture system, these have to be eliminated by sterilization using dry heat, moist heat (autoclaving), radiation and filteration. Sometimes tyndallization and pasteurization are also practiced depending on the nature of substrate and final product. For pharmaceutical and chemical productions, this step has to be strictly followed as per need of the process.

d) The next step followed is the inoculum preparation and then fermenter has to be inoculated containing cooled sterilized medium at the rate of 1-10%. The fermentation is carried out by controlling all the parameters strictly for a certain period and thereafter the product is obtained by filteration, purification, concentration and drying. The quality of product is monitored at this stage.

10.10 COMPUTER APPLICATIONS IN FERMENTATIONS

The computer application is gaining importance in fermentation industries. It serves two distinct purposes: i) evaluation of fermentation parameters and their impact on the synthesis of desired product in the cell; ii) on line fermentation control especially at the production scale.

Computers find wide acceptability in high valued low volume product formation mainly costly life saving drugs and chemicals. It is used for data acquisition such as information on pH, temperature, viscosity, aeration rate and O_2 and CO_2 content. It also helps in data analysis.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List the important varieties of fermented foods consumed all over the world.

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2. Define ‘Aerobic’ and ‘Anaerobic’ fermentation and cite some examples.

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3. Compare the solid-state fermentation (SSF) and submerged culture fermentation.

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4. What are the requirements of fermentation? Illustrate the significance of microorganism in the fermentation.

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5. Provide an account of computer applications in industrial fermentations.

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10.11 LET US SUM UP

Biotechnology has emerged as an important tool to improve the life of people. It implies the application of microorganisms, plants and animals. Fermentation is an important aspect of biotechnology and it has been in practice since time – immemorial. Both harmful (pathogenic) and useful (beneficial) microorganisms grow on different commodities and environment when physical (water activity, pH, temperature, humidity) and nutritional factors become favourable for their growth. These microorganisms modify the textural and chemical characteristics of food materials and thus make them highly nutritious and palatable. They enrich some of these agricultural food commodities with vitamins, minerals, amino acids and essential fatty acids. These fermented foods are classified into several categories based on the raw materials used for fermentation (fruits and vegetables, cereals, milk and fish and meat products etc.)

The methods of fermentation normally employed are solid state fermentation (SSF) and submerged culture fermentation both aerobic (presence of oxygen and anaerobic (absence of oxygen) conditions. In nature many microorganisms grow together thus mixed culture fermentation takes place whereas in industries one (monoculture) or two microorganisms with improved strains are used and their growth conditions are strictly monitored. Computers are employed in fermentation industries for different purposes.

10.12 KEYWORDS

Fermentation : Fermentation is the chemical transformation of the constituents of raw materials with microorganisms and their enzymes.

Harmful microorganisms : Spoilage and pathogenic microorganisms.

Useful microorganisms : Beneficial microorganisms (wine and beer producing, curd, cheese and bread making and ethanol production).

Homofermentative : The microorganisms only producing lactic acid.

Heterofermentative : Those microorganisms produce lactic acid along with acetic acid, formic acid and ethanol.

Aerobic fermentation : It is carried out in the presence of oxygen.

Anaerobic fermentation : Microorganisms grow in the absence of oxygen (Ethylalcohol, lactic acid, acetone, acetic acid, butanol).

Solid state fermentation (SSF) : Microorganisms grow on solid materials without the presence of free liquid.

Submerged culture fermentation : Microorganisms grows in the liquid medium in the presence of oxygen mostly.

10.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

- Emerging area of Science and technology.
- Application of microorganisms, plants and animals.
- Production of chemicals, value added products, food materials, medicines etc., commercially.
- A boon to people all over the world.
- A myriad of chemicals and products are produced by only microorganisms unlike plants and animals.

2. Your answer should include the following points:

- Change in chemical and physical characteristics of the raw materials.
- A process in which innumerable strategic chemicals (ethanol, medicines, harmones, vitamins) are produced by microorganisms.
- Production of bread, curds, cheese, wine, beer, whisky, rum and brand etc.,

3. Your answer should include the following points:
   - Causing fatal infectious and contagious diseases to human being, animals and plants.
   - Commercially producers of alcoholic beverages of different types from varieties of agricultural commodities, bread, lactic acid fermentation, amino acids, vitamins and antibiotics.
4. Your answer should include the following points:
   - Improves the shelf life of fruit and vegetables.
   - Improves the organoleptic quality.
   - Improves the nutritional quality and health benefits in foods.
   - A good method of storage of agriculture and food commodities.
   - Cheapest and simplest method of preservation.
5. Your answer should include the following points:
   - Fermented fruits and vegetables taken along with lactic acid bacteria lower the cholesterol level in blood.
   - Lowers the number of cardiovascular diseases.
   - Lactic acid producing bacteria present in foods inhibit the formation of carcinogenic compounds.

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - Fruits and vegetables, alcoholic and non-alcoholic beverages, cereals, milk products, fish products, products from pulses, legumes, meat products, starch crop fermented products.
2. Your answer should include the following points:
   - Growth of microorganisms in the presence of oxygen.
   - Growth of microorganisms in the absence of oxygen.
   - Ethanol, beer, acetone, butanol, biogas (aerobic).
   - Enzymes, aminoacids, vitamins and organic acid (anaerobic).
3. Your answer should include the following points:
   - Growth of microorganisms on solid materials for examples grits of cereals, fruits and vegetables, wheat and rice bran etc.,
   - The moisture content is usually maintained around of 32-35% (SSF: Solid state fermentation).
   - Tray fermenters are conventionally used (SSF).
   - Fermentation is carried out in a liquid medium containing 85% moisture (submerged).
   - Sophisticated expensive fermenters along with other equipments are needed (submerged).
4. Your answer should include the following points:
   - Microorganisms are responsible for the conversion of constituents into the desired product.
   - Needs highly potent strains of microorganisms.
   - A good medium for the growth of culture.

- The medium should have optimum quantity of carbon source, nitrogen source, vitamins, minerals, water, pH and oxygen.

5. Your answer should include the following points:

- Monitoring the functions of fermenters during operation.
- Data acquisition and data analysis.

10.14 SOME USEFUL BOOKS

1. Steinkraus, K.H. (1995) Hand Book of Indigenous Fermented Foods, Second Edition, Marcel Dekker, New York.

2. Campbell-Platt, G. (1987) Fermented Foods of the World, Butterworths, London.

3. Wood, B.J.B. (1985) Microbiology of Fermented Foods Vol. 1&2, Elsevier Applied Science Publishers.

4. Reed, G. and Nagodawitana, T.W. (1995) Biotechnology, Second Edition, VCH, New York.

UNIT 11 FRUIT AND VEGETABLE-BASED FERMENTATIONS AND THEIR COMMERCIAL PRODUCTS

Structure

11.0 OBJECTIVES

After studying this unit, you should be able to:

- infer the commercial importance of fruit and vegetable based fermentations;
- state the significance of lactic acid fermentation in fruits and vegetables; and
- describe the state of art of sauerkraut, cucumber, kimchi, sinki and fermented pickles production.

11.1 INTRODUCTION

The importance of food fermentation has been highlighted earlier. It is evident that fermented foods are an intricate part of the diet of people in all parts of the world. These are always used as condiments accompanying the main dish. These foods are prepared from plant and animal sources. Fermentation primarily to preserve these commodities and also add flavour and change the texture in order to suit palatability and acceptability. Another important purpose is adding variety to the monotonous diet. Since it has been practiced since time immemorial, it is a house-hold art throughout the world. In recent years, a number of technological and biotechnological developments are taking place and several products are produced on commercial scale.

In early days, people used to collect vegetables and tried to preserve by adding salt. Chinese used to take acid-fermented vegetables during the 3rd century. Korean developed *Kimchi* made from acid fermented cabbage, radish etc., Fermented cabbage is popular in the Western World. Africans evolved the process for acid fermentation of maize, sorghum and tapioca. Even though nothing was known about the technology or microbiology and also about the nutritional quality of the products, the advantages of acid fermented vegetables, fruits, cereals and milk were well known to people during those days.

During the early twentieth century, it became known that microorganisms are responsible for physico-chemical textural and flavour and taste changes in fermented products. In recent years, some of the fermented foods have been scientifically investigated and based on the microbiological and biochemical information, technologies have been developed for commercial production. Since microorganisms are the key to these fermented food production, these fermented foods can be grouped for convenience as follows:

i) Acid fermentation preserving fruits, vegetables, milk, cereals, fish and meat etc., and enhancing orgnoleptic and nutritional quality.

ii) Protein rich vegetarian foods from legumes and seeds (Tempeh, Oncom etc.).

iii) Alkaline fermentation from beans (Kinema and African fermented foods).

iv) Alcoholic foods and beverages (Ethanol is a major product).

v) Sauces, pastes etc.

Microorganisms grow on the substrate and based on the chemical nature of the substrate, they bring about changes. Two types of acids are predominantly produced viz. lactic acid and acetic acid by microorganisms and thus a variety of products from agricultural commodities are produced especially from milk, cereals, and fruits and vegetables. The other important group of fermented foods is the protein enrichment and modification mainly from soybeans, peanuts and other legumes and pulses. Among beverages, alcoholic fermented beverages e.g., wine, beer top the list all over the world.

In recent years, vegetarian foods are considered to be ideal for human health. Among these lactic acid producing bacteria fermented foods are the best as these organisms tend to help in avoiding cardiovascular and heart diseases, cancer and several other gastrointestinal problems. The advantages of acid food fermentation are:

i) They avoid spoilage of foods and mould and bacterial toxins production.
ii) They preserve the food and assure the foods safety.
iii) They modify the flavour of the original ingredients and improve the nutritional value.

Since canned and frozen foods are beyond the reach of majority of people especially in rural areas, acid fermentation of agricultural commodities remains one of the most simplest and inexpensive method. However, in India acid fermentation of vegetables and fruits are not common as compared to European, Oriental and African countries. The raw materials containing high sugar content favour usually ethanol generation and its conversion to acetic acid. The fruits and vegetables having low level of sugar, allow lactic acid producing bacteria to proliferate which lowers the pH around4.0 due to lactic acid production.

11.2 LACTIC ACID FERMENTED FRUITS AND VEGETABLES

Fermented vegetables are common ingredient of European diet. Sauerkraut, olives and cucumbers are often fermented. The method of vegetable fermentation has been standardized over the centuries both for natural (spontaneous) or addition of starter cultures. The lactic acid producing bacteria grow on the substrate (vegetables) and convert sugar into acids (lactic and acetic). The gradual disappearance of carbohydrate (carbon content) leads to the production of lactic acid which ensures food stability. The pH about 4 of the fermented products inhibits the growth of spoilage microflora and pathogenic organisms.

Salt is added in good quantity which promotes the growth of lactic acid producing bacteria and checks proliferation of contaminating and spoilage microorganisms.

Fruits and Vegetables suitable for Lactic Fermentation

- Cabbage, cauliflower, broccolys, mustard
- Carrots, turnips, beetroots, radish
- Cucumber, Olives, tomatoes, peppers, green-beans and green peas
- Onion and garlic
- Apples, pears, green mangoes, banana, lemon, lime

11.3 SAUERKRAUT (CABBAGE) FERMENTATION

Sauerkraut or Sauerkohl is a German term which means *'Sour Cabbage'* Sauerkraut is extensively used in the North America (Canada and U.S.A.), Germany, Holland, France, U.K. and other European countries. Cabbage ('*Brassica oleracea*) normally grown in cold climate is found to be suitable for the fermentation purpose.

i) Processing

Fresh cabbage is taken, cleaned, trimmed and shredded into 2-5mm size and finally filled into wooden vats or cement tanks. Salt is added at the rate 2.25% and mixed thoroughly. The top portion of the vat or tank is covered with plastic and enough weight is applied in order to make it compact and allow anaerobic conditions prevail for fermentation. When weight is applied, the salt dissolves in the sap which is expressed by the pressure and by osmosis it comes out from the cells. The leaves respire for sometime and oxygen is utilized and thus anaerobic conditions are created. The leaves shrink in size due to water removal. A spontaneous lactic acid fermentation follows. Fermentation is done for about 30 days or more until 1% lactic acid is formed. The Sauerkraut is removed from the vat and packed in cans, glass or plastic containers. In cans the fermented product is pasteurized at 74^{o}C for 3 minutes. Sodium benzoate or potassium metabisulphite is added when product is packed unpasteurized. It is stored at $\pm$ 5^{o}C.

Fresh Cabbage

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Trimming, Cleaning and Shredding (2-5 mm)

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Salting at 2.25% (w/w)

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Fill into Vatsor Containers

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Cover and seal with proper weight

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Ferment

↓

Pasteurize

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Can or package in plastic bags with preservatives

Figure 11.1: Sauerkraut (Cabbage) Fermentation

ii) Microorganisms Involved in Fermentation

Initially the shredded and processed cabbage leaves contain very high number of aerobic bacteria with low counts of lactic acid bacteria. During fermentation, the number of lactic acid bacteria increases suppressing the growth of undesirable organisms and a distinctive flavour of sauerkraut develops with about 1% of lactic acid content. The microorganisms follow usually the following pattern in succession: *Streptococcus faecalis, Leuconostoc mesenteroides, Lactobacillus brevis, Pediococcus cerevisiae, Lactobacillus plantatrum.* Initially heterofermentative nominate the numbers which is taken over by the homofermentative type of microorganisms. Sometimes a previous batch brine is added as a starter culture to facilitate quick fermentation.

iii) Spoilage

Sometimes fermented products are very badly spoiled by contaminating bacteria causing off flavours and colour and undesirable texture. Temperature, salt concentration and sanitary conditions are important to control the desired fermentation. Lower temperature around 7-10^{o}C favours slow growth of bacteria and thus allows good fermentation. In traditional system, fermentation is allowed for 6 months.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List some of fruits and vegetables used commonly for fermentation and the mode of lactic acid production by the lactic acid producing bacteria.

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2. Define the word sauerkraut.

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3. Explain, how sauerkraut is prepared.

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4. Cite some microorganisms involved in cabbage (kraut) fermentation.

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5. What are the causes of spoilage of sauerkraut?

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11.4 CUCUMBERS FERMENTATION

Cucumbers (*Cucumis sativus)* are grown throughout the world. It is reported to have been originated in India. A number of varieties of cucumbers are cultivated in fields or greenhouses for table or pickling purposes.

i) Processing

Cucumbers are washed after selecting them and placed in a covered tank containing a salted and acidified brine. The brine is normally acidified (vinegar or acetic acid) to pH 4.5.The salt concentration of the brine is maintained between 5-8%. Too little salt less than 5% favours the growth of enterobacteriaceae bacteria. Higher levels of salt allows growth of yeasts. After the initiation of fermentation, almost everyday the brine is buffered with sodium acetate. During fermentation, contamination with yeasts is observed and therefore, to avoid bloater formation, the brine is purged with nitrogen or air. Potassium sorbate (0.035%) is also added to check the growth of yeasts and moulds preferably if fermentation is done at smaller scale. Fermentation if it is carried out at 15-20^{o}C, it takes normally 3 weeks to 1 month.

ii) Microorganisms involved in the fermentation

Streptococcus faccalis, Streptococcus lactis, Leuconostoc mesenteroides, Pediococcus pentosaceus, Lactobacillus brevis, Lactobacillus plantarum, Lactobacillus bavaricus are usually noticed during the fermentation. Controlled fermentation and pure culture fermentation have been studied but not commercially exploited. Glucose and fructose are converted to lactic acid, acetic acid, ethanol, mannitol and carbon dioxide. About 1.1%, lactic acid is present after the fermentation. Textural properties after fermentation is important. A firm and crisp texture is desired. A clean flavour is also desired.

iii) Spoilage

Bloater formation is observed due to the growth of gas forming microorganisms e.g. yeasts, bacteria and other contaminating organisms. Bleaching of the green colour of cucumbers takes place due to exposure of fruits to sunlight. Offensive flavours are produced due to the formation of butyric and propionic acids.

11.5 KIMCHI FERMENTATION

Kimchi is a major condiment of Korean diet. It is a popular dish served at every meal along with cooked rice. Kimchi is a fermented product, gaining popularity in the United States of America and other countries. It is made from cabbage and other vegetables like radish, mustard greens, cucumbers, green onions, Chinese leeks, turnips and green peppers, spinach, pumpkins and egg plants.

i) Processing

Good quality cabbages are selected, cleaned and cut into smaller pieces. The cut cabbage is placed in a brome solution containing 5-7% salt concentration for 12 hours. The brined vegetables are rinsed and drained. Seasoning ingredients are thoroughly mixed and filled in earthen jars or glass jars. The jars are buried (80-90% of container depth) underground. These are covered on the top with bundles of rice straw to protect from sunlight and rain. This technique is followed in the rural areas. In urban areas the mouth of the jar is covered with a cloth piece and kept in shaded places. Low temperature is considered to be ideal for slow fermentation. Usually less than 15^{o}C temperature is optimum for good quality Kimchi.

ii) Microorgansims involved in the fermentation

The microorganisms involved in Kimchi fermentation are *Leuconostoc mesenteroides, Streptococcus faecalis, Lactobacillus brevis, Lactobacillus plantarum, Pediococus cerevisiae.* The aerobic bacteria found are species of *Achromabacter, Flavobacterium* and *Pseudomonas.* The main bacterium responsible for Kimchi fermentation is *Leuconostoc misenteroides.* The fermentation is initiated by *Leuconostoc mesenteroides* and terminated by *Lactobacillus plantarum / Lactobacillus brevis.*

The organic acids produced during fermentation contribute to the final flavour of Kimchi. The organic acids normally noticed in Kimchi are citric, fumaric, oxalic, malonic, malic and succinic acids. Freshly fermented, good quality Kimchi should have distinct red or green colour with pleasant flavour and taste.

iii) Spoilage

Softening is the major problem in Kimchi fermentation. Yeasty and off flavours also effect the quality of the fermented product.

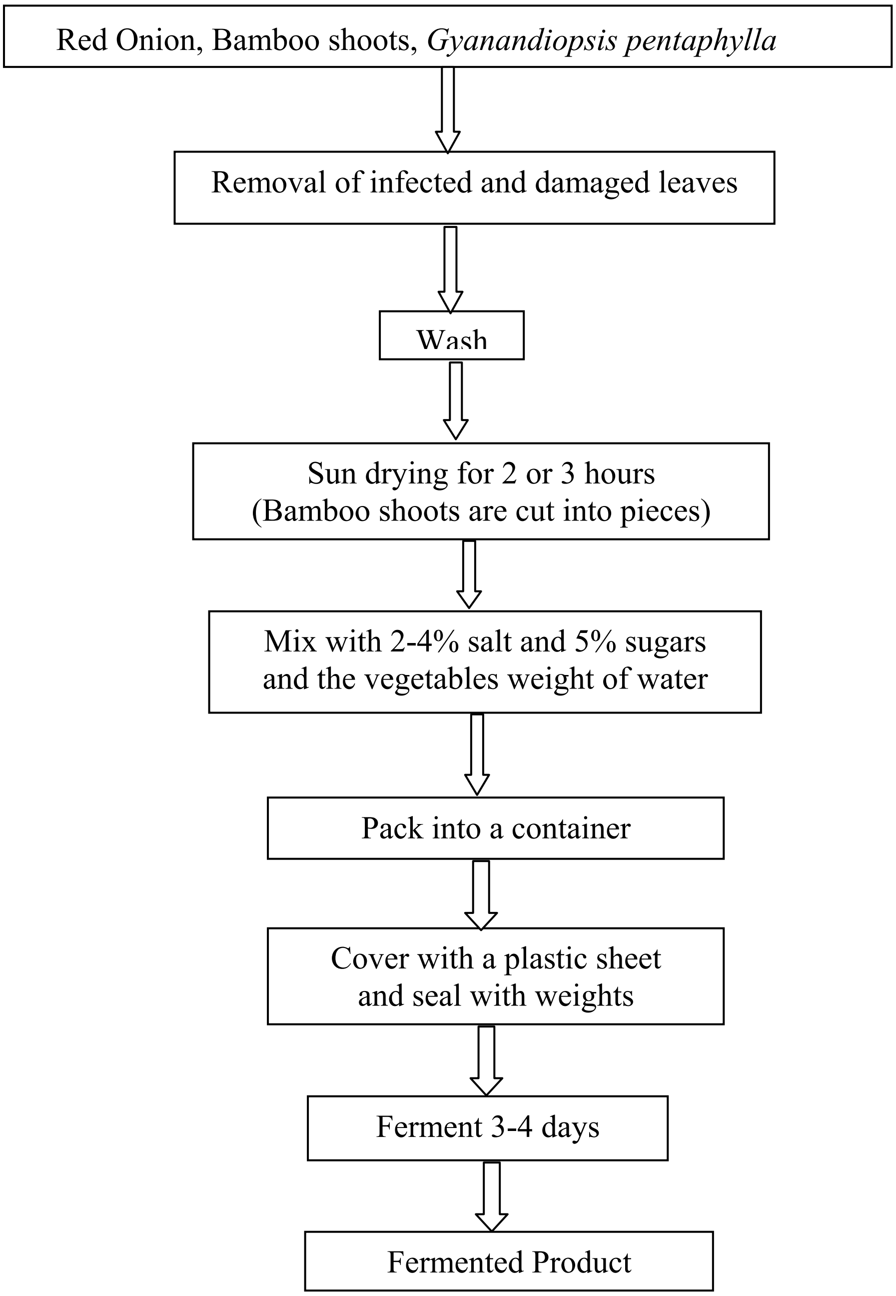
11.6 INDIAN SINKI FERMENTATION

Sinki is consumed as a pickle in the Himalayan belt of India, Nepal and Bhutan. It is prepared from the tap root of radish. Fresh radish roots are washed and placed outside for sun drying for 1 or 2 days. These are shredded and washed again and packed tightly into an earthen ware or glass jars, sealed and left for fermentation. Fermentation is carried out for 15-30 days at room temperature around 30^{o}C. Initially *Lactobacillus fermentatum* grows followed by *Lactobacillus brevis* and *Lactobacillus plantarum.* The pH drops to3.3 and acidity rises to 1.28%. When fermentation is over, the fermented radish is sundried for 3-5 days. It is fried with salt, tomato and green chilli. The fried mixture is then boiled in rice water and served hot as soup along with the main meal.

11.7 FERMENTED PICKLES

i) **Pak-Sian-dong and Related Fermentations** (Fermented bamboo shoots and fermented red onion)

These are the common pickles of Thailand. The fresh vegetable is washed thoroughly and spread on a mat in the air or sunlight in order to loose water and tissues to wilt. It is mixed with 2% salt, 4% sugar and the same quantity of water and kept in a tight container. It becomes ready for consumption in 3-4 days. Acidity normally reaches to 0.8% with pH around 3.9-4.0.



Microorganisms involved : *Leuconostoc mesenteroides, Pediococcus cerevisiae, Lactobacillus plantarum, Lactobacillus brevis, Lactobacillus fermentii.*

Figure 11.2: Pickles (fermented) of Thailand

ii) Malaysian Pickles

Home made pickles are common in most of these countries especially in rural areas. Fruits and vegetables which are relatively sour, are used for pickle preparation. Many types of fruits and vegetables are used depending upon the availability and seasonality. The common vegetables used are: gherkins, cucumbers, ginger, onion, leek, chilli, bamboo shoots, unripe

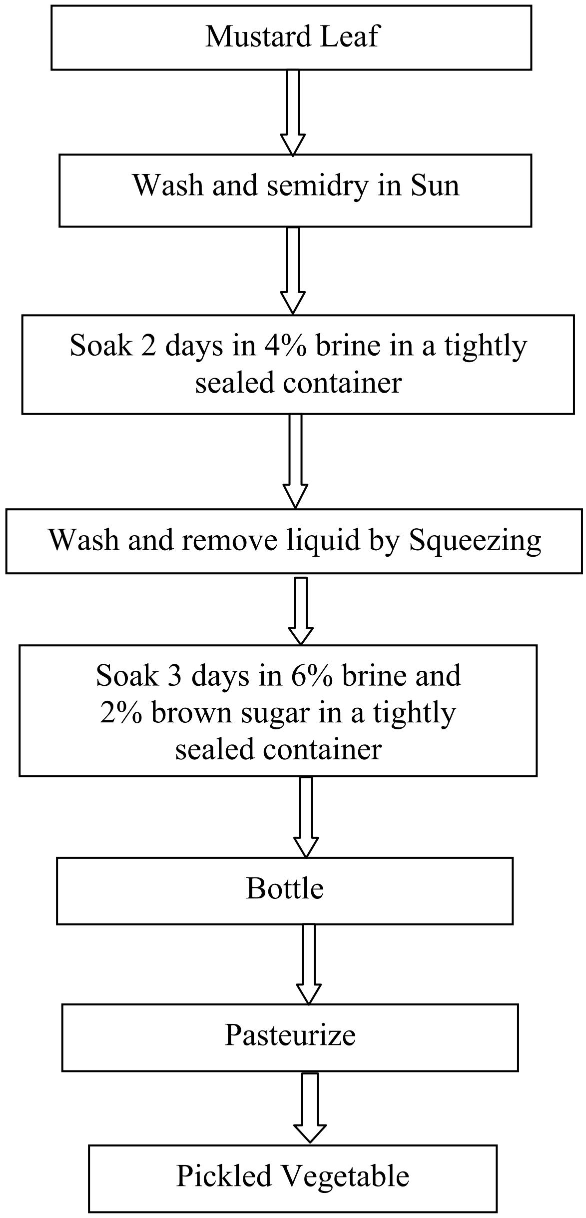


Figure 11.3: Malaysian pickled vegetable

mango, papaya, lime, lemon and nutmeg. In all these fermentations higher level of crystal salt or brine is used in curing the tissues. Sugar and other fermentable carbohydrates, dilute vinegar, and spices are also added. It appears to be a simple process but the quality differs from house to house. Pickles undergo a bacterial lactic acid fermentation. The same group of microorganisms are involved in the fermentation. Fermentation takes about 8 days depending upon the substrate.

In India, several varieties of pickles are prepared both for indigenous consumption and export purposes. We usually prefer non-fermented pickles preserved in edible oils. The quality and taste differ based on the ingredients used. Bamboo shoots pickles, brinjal and mixed vegetable pickles are common in North India. Some of these are exotic in nature prepared at house-hold level.

iii) Lactic Fermented Fruits in European Countries

Fruits are cleaned and blanched at 50-60°C to destroy undesirable bacteria. After the addition of *Lactobacillus acidophilus* or *Lactobacillus bifidus* the product undergoes to lactic acid fermentation. The fruit is shredded and pulverized and pasteurized and finally goes for marketing.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Highlight the importance of cucumber fermentation and different steps involved in fermentation.

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2. Name the countries where Kimchi is prepared and used. List vegetables used in Kimchi fermentation.

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3. Explain about the Indian sinki fermentation and method of its preparation.

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4. Give a brief account of fermented bamboo shoots and fermented red onion.

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11.8 LET US SUM UP

Fermentation of different types of agricultural commodities has been practiced with an aim to preserve them and also add exotic flavour and change the texture. Fermented fruits and vegetables have been in use mostly as condiments in order to avoid monotonous diets. Lactic acid producing bacteria grow luxuriantly in favourable conditions on fruits and vegetables and produce good quantity of lactic acid and other acids and antimicrobial substances which lower down the pH and thus check the growth of spoilage and pathogenic microorganisms. It is a simplest method of preservation. Sauerkraut and cucumber fermentations are the typical examples. Kimchi of Korea, Sinki of Indian sub-continent, fermented bamboo shoots and red onion and Malaysian pickles are produced commercially and consumed by the people. Lactic fermented fruits are becoming popular in European countries.

11.9 KEYWORDS

Sauerkraut	:	Fermented cabbage.
Kimchi	:	Korean fermented product (cabbage).
Sinki	:	Indian fermented product from radish.
Pak-Sian-dong	:	Fermented bamboo shoots of Thailand

11.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Cabbage, cauliflower, broccoli, mustard, carrots, turnips, beetroots, radish, cucumber, olives, tomatoes, peppers, green beans, peas, onion, garlic, apple, pears, green managoes, banana, lemon and lime.
   - Lactic acid producing bacteria grow on vegetables and fruits and convert sugars into acids (lactic and acetic).

2. Your answer should include the following points:

   - A German term meaning ‘Sour Cabbage’.

3. Your answer should include the following points:

   - Fresh cabbage → trimming, cleaning and shredding → salting → filling into vats → covering the vat and applying weight on the top → allowing fermentation → pasteurization → packing with preservatives.

4. Your answer should include the following points:

   - *Streptococcus faecalis, Leuconostoc mesenteroides, Lactobacillus brevis, Pediococcus cerevisiae.*

5. Your answer should include the following points:

   - Good sanitary conditions needed while processing cabbage for fermentation.
   - Low temperature and appropriate salt concentrations favour good fermentation and the final product.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Widely cultivated in India in all the States irrespective of climatic changes Selection of fruits → washing → placing fruits in brine 5-8% (pH 4.5 adjusted with vinegar) → allowing natural fermentation at 15^{o}C → purging nitrogen to avoid bloater formation → fermentation for one month.
   - *Streptococcus faecalis, Streptococcus lactis, Leuconostoc mesenteroides, Lactobacillus brevis, Lactobacillus plantarum*.

2. Your answer should include the following points:

   - A major condiment of Korean diet.
   - Vegetables like cabbage, radish, mustard (green), cucumbers, green onions, Chinese leeks, turnips, green peppers, pumpkins, etc.

3. Your answer should include the following points:

   - Radish roots → sundrying for 1-2 days → shredding → packing tightly in an earthen vessel → sealing of the mouth of vessel → allowing fermentation for 15-30 days → fermented radish sundried → used as a condiment for soup.

4. Your answer should include the following points:

   - Fermented vegetables of Thailand.
   - Fresh vegetables washed and spread on a mat and sundried.
   - After sundrying 2% salt and 4% sugar are added and mixed with the vegetables quantity of water and placed in a container.
   - Fermentation normally takes 3-4 days.

11.11 SOME USEFUL BOOKS

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3. Steinkraus, K.H., Cullen, R.E., Pederson, C.S., Nellis, L.F. and Govitt, B.K. (1983) Handbook of Indigenous Fermented Foods, Marcel Dekker Inc, New York.

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UNIT 12 FRUIT-BASED ALCOHOLIC BEVERAGES

Structure

12.0 OBJECTIVES

After studying this unit, you should be able to:

- discuss about different varieties of wine produced commercially in different parts of the world;
- know the microorganisms involved in wine fermentation and factors influencing its quality;
- explain the method of wine production and different practices involved before and after fermentation; and
- get information on clarification of fermented juice and maturation of wine.

12.1 INTRODUCTION

Production and consumption of fermented beverages is an old practice. It has been referred in Vedas. In the previous chapter, how lactic acid from plant constituents is produced to preserve the food along with favourable organoleptic changes are discussed. Similarly many fruits contain very high amounts of free sugars which are readily converted into ethanol and carbon dioxide with the help of yeasts and thus alcoholic beverages are produced.

Wine is normally referred as a by-product of grapes (*Vitis vinifera*). However, wine can be produced from any fruit or flower rich in soluble sugars. Still most of the wines are produced from grapes throughout the world. European, Western World, North America especially colder climate countries are the major producers and consumers of alcoholic beverages. In these countries, 75% of the crop is diverted for wine production. France and Italy are the major producers of quality wine. Due to several reasons including the taboo attached to consumption of alcoholic beverages, fruit wine and brandy industries have not developed well in India. We meet most of our demand through import although India is the second largest producer of fruits and vegetables.

12.2 TYPES OF WINE

As stated already, the pressed juice of grapes or any fruit rich in soluble sugars if fermented by yeast/s or spontaneous natural fermentation, it results in the ethanol (wine) production and its disstilate is known as “Brandy”. White wine is produced from the grapes usually cultivated whereas the red variety or Bangalore blue grapes having purplish red skin give rise to “Red Wine”.

Different types of commercial wines are listed below:

- *Champagne* is a foaming wine which contains dissolved carbondixoide.
- *Sparkling* wine is produced by carbonation by injecting carbondixoide into the wine.
- *Liqueur Wine* is sweet with a higher content of alcohol.
- *Sherry* is a fortified wine with two distinct styles, the first being dry wine (without any sweet taste) consumed as an appetizer before meals and the other being olorosos sweetened wine taken after meals.
- *Port* in which wine is stored in a wooden cask or Hintage ports. During maturation the type of barrel used for aging contributes to quality of wine.
- *Vermouth* is a flavoured wine in which different varieties of herbs and spices are added.
- *Brandy*: It is a distilled wine stored mostly in wooden cooperage or casks.

12.3 FRUITS USED FOR WINE-MAKING

Sugars present in fruits are responsible for quick fermentation and other constituents contribute to the flavour and aroma of the wine. Grapes, apple, pear, custard-apple, mango, jamun, coconut sap, palm sap, pomegranate, banana, guava, ber, plum, orange, litchi, dates, pineapple, strawberry, raspberry, cherry, grape - fruit etc. can be used for wine making. The technology for grape wine has been developed in the western world and thus quality products are produced commercially. There are many reasons for non-acceptability of non-grape fruits for commercialization. Many of these fruits contain low levels of soluble sugars and their fermentability is poor. Extraction of juice from these fruits poses serious difficulties. Some of these have very high or low concentrations of acidity which influences the quality of wine considerably. Bitterness and some other organoleptic defects of the final product are the other serious problems for commercialization.

12.4 IMPORTANT FACTORS INFLUENCING THE QUALITY OF WINE

i) Fruits and their chemical composition

Grapes are the best fruit for quality wine production. It has been found that the cultivation conditions of grapes influence the quality of wine. Fruit variety, sugar content, additives, pulp or juice yield, yeast strain for fermentation, filteration, maturation and preservation of wine, all affect the final quality of wine. Yeast is the key for alcoholic fermentation or ethanol production and the factors which influence the growth of yeast also affect the quality of the wine. The sugar content of selected fruits is given in Table 12.1.

Table 12.1: Sugar and acids composition of fruits

Fruit	Total Sugar (% Fresh Weight)	Acid (% of Tartaric acid)
Apple	8-10	0.9 - 1.4
Banana	18	0.3 - 0.4
Grape	15 - 22	0.4 - 1.3
Orange	9 - 10	0.8 - 1.1
Pear	9 - 11	0.2 - 0.4
Strawberry	5 - 6	0.6 - 1.5

ii) Temperature

The temperature of must (fruit juice) strongly influence the yeast growth. The yeast normally used for wine fermentation is strain of *Saccharomyces cerevisiae*. The optimum temperature for wine fermentation ranges between 22-27^{o}C. Quality white wine is produced at lower temperature 10-15^{o}C where as red wine needs higher temperature which ranges between 20-30^{o}C.

iii) Ethanol Content

As we know one mole of glucose gives rise to two moles of ethyl alcohol (ethanol) and two moles of carbon dioxide during the fermentation.

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$$

Beyond certain concentrations of sugar in the must/mashes, the yeast growth is stopped. Similarly after 10-12% (v/w) ethanol in the must, the growth of yeast declines considerably. There are a number of methods known to enhance the ethanol tolerance of the selected strain used for fermentation.

iv) Carbohydrate and Energy Sources

It is apt to think that the wine is produced from the sugar and flavour containing chemicals present in the fruits with the help of yeast/s. It is, therefore, important to know the type of sugars and their quantity present in the must. Glucose, fructose, sucrose and maltose are easily utilized by the yeast (*Saccharomyces cerevisiae*) for its growth and ethanol and carbon dioxide production. Lactose, pentoses, dextrin, starch or higher molecular weight carbohydrates or poly-saccharides are not utilized by the yeast. Usually 0.8-1.3% of sugar is utilized for the growth and rest is used for ethanol generation. At sugar concentration of 25% and above in the must, the yeast growth is slowed down. Except grapes, due to low concentration of sugars in other fruits, the mash has to be supplemented with sugars.

v) Carbon dioxide and Pressure

Carbon dioxide is produced during the fermentation and if higher pressure is built then it inhibits the growth of yeast. However, the sparkling wine is produced under the carbon dixoide pressure in a closed container.

vi) Sulphur Dioxide (SO_2) and other Agents

Sulphur dioxide is added to the must or juice in order to bring down the number of contaminating microorganisms viz., moulds, yeasts and bacteria. The other chemicals tried are salicylic acid, bromoacetic acid, ethylene oxide, benzoic acid and sorbic acid. SO_2 is preferred because it is less toxic to human beings.

vii) pH and Acids

Normally the organic acids present in fruits do not interfere with yeast fermentation. Other organic acids such as acetic, butyric, propionic and fatty acids have inhibitory effect on yeasts. If the pH is below 3.0, the alcoholic fermentation is delayed considerably.

viii) Growth Factors

Biotin, inositol, nicotinic acid, pantothenic acid, p-aminobenzoic acid, pyridoxine and thiamine are needed for the growth of yeast.

ix) Minerals and Pesticides

Iron, copper, zinc and aluminium are present in the final product. Fermentation is not usually affected by the presence of lower concentrations of these metals. They normally come through presses or other equipments used. Pesticides are normally used to control pests which infest trees and fruits. Their residues in the wine is highly objectionable.

x) Nitrogen Sources

For the growth of yeast, nitrogenous compounds are needed. The amino nitrogen present in the must supports the growth of yeast. There are many factors e.g. method of juice preparation, ripening of the fruit, variety and several other cultivation parameters, which influence the amounts of these chemicals. Some of the fruits are deficient in them and therefore, supplementation is necessary. The inorganic nitrogenous salts usually used in wineries are: $(NH_4)_2$ HPO_4 or $(NH_4)2SO_4$ upto 0.3 g/l.

xi) Tannin/Phenolic Compounds

Tannin and phenolic compounds are present in the fruit juice. Their concentrations differ from fruit to fruit. Tannin normally does not affect the growth of *Saccharomyces cerevisiae* (yeast).

xii) Juice Clarification

In recent years, grape and apple juices are being treated with pectinolytic enzymes for better yield and quality of wine. However, in wine manufacture, cloudy or turbid juice is preferred. Bentonite is added to improve the fermentation. However, the fruit pulp of non-grape fruits have to be treated with pectinolytic enzymes. There are many reports that musts which contain insoluble particles ferment quickly. Therefore, insoluble materials such as filter aids or wheatflour is added in the musts.

12.5 MICROORGANISMS INVOLVED IN WINE-MAKING

i) Yeasts

The quality of wine depends on the yeast strain used for fermentation. The quick growth of yeast and an efficient conversion of sugar into ethanol decide mostly the quality of wine. *Saccharomyces cerevisiae* is the most important yeast for the juice (must) fermentation. Besides this yeast, there are numerous other species of yeasts which are also present and some times they spoil the wine.

Saccharomyces cerevisiae and numerous other yeasts such as *Kloeckera apiculata, Hansenula anomala, Candida stellata, Candida krusei* are also present in grapes. Besides these, *Schizosaccharomyces pombe, Saccharomyces bayanus, Saccharomyces fermentii* have also been isolated from grapes and various other fruits.

When grapes are crushed, within a few days *Saccharomyces cerevisiae* grows and multiplies to a higher number of cells. In the case of spontaneous fermentation, inoculum is not added and the yeasts present on the substrate and equipments serve as a source of starter culture. In order to maintain the quality and yield of wine, wineries all over the world are using a particular standard strain of *Saccharomyces cerevisiae.* It also provides protection from the 'Killer yeast'. Killer yeasts are infected with a virus that destroys the used strain of yeast for fermentation. Some times an active dry yeast culture about 0.1 g/L is also added to accelerate the fermentation.

It is an important question why wineries prefer *Saccharomyces cerevisiae?* It is tolerant to high levels of sugar of fruit juices, tolerates high ethanol concentration, invariably grows even at low pH, ferments must at low temperature and resistant to sulphur dioxide level which suppresses the growth of bacteria, yeasts and moulds. Apart from these, it induces desirable aroma in the wine. That is the reason it is called as wine yeast.

Morphology of *Saccharomyces cerevisiae*

It is spherical to ellipsoidal in shape with 8 × 7μ of size depending on the growth medium. It multiplies by budding.

Most strains of *Saccharomyces cerevisiae* are capable of producing alcohol upto 16%.

ii) Microorganisms other than yeasts in Winemaking

Bacteria

Lactic Acid Bacteria *Leuconostsoc oenos* *Pediococcus pentosan, Pediococcus purvislus, Lactobacillus* plantarum *Lactobacillus* fermentum	Responsible for malo-lactic fermentation and spoilage

Acetic Acid Bacteria

Acetobacter and *Glucanobacter spp.*	Responsible for Vinegar taste, spoilage and stuck fermentation.
Bacillus and *Clastridium* spp.	Spoilage

Fungi

Botrytis cinerea *Penicillium* sp. *Aspergillus* sp.	Botrytized wine, spoilage, corkytaints
Actinomycetes *Actinomyes* spp. *Streptomyces* spp.	Earthy and corky taints.

12.6 PREFERMENTATIVE PRACTICES IN WINE-MAKING

i) Stemming, Crushing and Juice Separation

Fruit stalks, seeds and skins (pomace) are removed and then fruits are crushed and macerated. To check initiation of fermentation, white grape juice is chilled to about 10°C. Sulphur dioxide is also added to retard the multiplication of microorganisms. Red grapes are given longer time for maceration at 24-27°C which helps the extraction of pigments and phenolic compounds. Pressing separates the juice from the seeds and skins of the fruit. Large wineries use dejuicers for this purpose.

ii) Clarification

If juice is allowed for some hours for settling, the solid materials and suspended particles get separated and a clear juice is obtained. However, in commercial wineries filter aids such as bentonite is used and juice is centrifuged at low speed or passed through filter press.

iii) Juice/Must Adjustment

Total acidity of must is important for the final quality of wine. If acidity is less than the desired concentration, citric or tartaric acid is added appropriately. Higher level of acidity is retarded by the supplementation of calcium or potassium salts. Sugar is added in the must when sugar content is too low in the fruits. It is known as chaptalization in wine making. The other techniques followed for increasing sugar concentration are reverse-osmosis, cryoextraction and entropie concentration.

12.7 FERMENTATION

Fermentation is an energy releasing metabolism in which the electron donor and electron acceptor are organic compounds. In wine fermentation, glucose and fructose are the electron donors and ethanol is the acceptor. Glycerol, acetic acid, acetaldehyde and succinic acid are also electron acceptors which are produced in the must along with traces of diacetyl and fusel (higher alcohols).

Fermentation is done in a vat (open top) or tanks (sealed top). As stated earlier, both spontaneous and starter (inoculum) addition fermentation is practiced for wine making. During the initial stages, aerobic yeasts *Hansenula anomala* and *Klockera apiculata* are active. Subsequently they are taken over by the *Saccharomyes cerevisiae. S. cerevisiae* multiplies at a fast rate within 3 to 4 days and then ethanol production follows rising its level gradually and steadily.

12.8 SPOILAGE OF FERMENTATION AND WINE

Due to over clarification of juice/must and the presence of high number of wild yeasts having killer viruses and some other reasons some times fermentation does not proceed well. It is referred as the 'Stuck Fermentation'. Several species of lactic acid bacteria e.g. *Leuconostoc oenos, Lactobacillus* and *Pediococcus* spp. grow in the must and convert malic acid into lactic acid. Malic and tartaric acids are the major constituents of grape juice. They spoil the taste of wine. The wine and cider are spoiled by the acetic acid producing bacteria. They grow on the surface and oxidize ethanol to acetic acid. Similarly wild yeasts grow on the surface of stored wine and spoil the product. The sugar present in wine is converted into lactic acid by several spoilage microorganisms. Butyric acid bacteria, slime producing bacteria and moulds spoil the final stored product. Changes in colour of wine take place due to oxidation. It is, therefore, necessary to take care while carrying out the fermentation and during the maturation and storage of wine.

12.9 POST-FERMENTATION PRACTICES

i) Clarification and Stabilisation

Clarification refers to methods adopted for clear wine for bottling while stabilization assures that wine remains clear after bottling. Fermented must is allowed to settle for clarification. Dying yeast cells, grape cell remains, precipitated tannins and crystallized salts are removed. Clarification of wine is sometimes achieved by centrifugation.

ii) Fining

To remove colloidal materials, fining is practiced using filter aids bentonite, kiesselghur, silicondioxide, gelatin, albumin and isinglass.

iii) Centrifugation

It is done to remove fine particles.

iv) Filtration

Sometimes filtration is done with a courser filter but membrane filters are used to remove fine particles and live cells of microorganisms.

v) Crystallization

Crystallization of potassium and calcium tartrate salts occurs in wines. It has to be removed by the cold filtration adding salt at low temperature (-5^{o}C). Crystallization is undesirable for expensive wines.

vi) Haze formation

Normally soluble proteins and tannins precipitate in the must and lead to haze formation. The judicious addition of pectinase, β-glucanase or mixture of Kisselghur and gelatin prevents the haze formation.

vii) Adjustment of Factors

Adjustment of acidity, pH, sweetness, alcohol content and decolouration of wines are practiced based on the requirement of the product in the market. Blending is done all over the world in order to get the desired fragrance.

viii) Maturation

Freshly prepared wine is always found to be harsh with yeasty flavour. Maturation develops the mellowed wine taste with fruity and desired flavour. The quality of wines depend on the maturation and ageing. The maturation period extends upto 6 to 12 months. There are several methods used for maturation. The oldest and traditional method is to allow maturation of wine in the same barrel in which fermentation occurred. The other method is to employ oak wood barrels which results in the best quality of wine. Long oak strips or chips are dipped in the filtered wine and maturation is allowed to take place for more than a 6 months. Several chemical changes take place during this process.

Bottling

Dark amber colour glass bottles with a distinctive neck are commercially used. Usually oak cork are used as a closure conventionally.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define wine and give examples of different varieties of wine used all over the world.

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2. Explain, how wine is produced from fruits.

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3. What is 'MUST', name some yeasts involved in wine fermentation?

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4. What does the 'Killer yeast' indicate?

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5. Why does winery prefer *Saccharomyces cerevisiae?*

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6. What are prefermentative practices in wine making?

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7. What do you understand by the 'Stuck fermentation', Provide information about post-fermentation practices?

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12.10 WINE FROM DIFFERENT VARIETIES OF FRUITS

i) Apples

Cider and wine is produced from apple. Cider is a low alcoholic drink, contains alcohol between 4 to 6%. The apple varieties should have moderate amounts of phenolics. The higher juice containing varieties are preferred for cider fermentation. Apple juice or concentrate is used for wine fermentation. The alcohol content in apple wine ranges between 11 to 14%. Before fermentation apple juice is supplemented with cane sugar. Sometimes ammonium chloride or phosphate are also supplemented in the juice for fermentation.

ii) Custard apple

Annona squamosa is a tropical fruit. Since it is rich in fermentable sugars and delicate flavour, its pulp after the removal of seeds and skin can be used for wine making. The juice obtained is ameliorated to 23^{o} brix and acidity 0.7%, phosphate 0.05% and 125 ppm SO_2 and nitrogenous salts. The must (juice) is inoculated with *Saccharomyces cerevisiae* and fermentation is carried out.

iii) Pear wine

Perry or pear wine of good quality is prepared from pears with high tannin contents. Since it is deficient in nitrogen, an exogenous addition of nitrogen is necessary. Perry fermentation is carried out at temperature of 20-22^{o}C.

iv) Mango wine

Mangoes (*Mangifera indica* Linn.,) is a tropical fruit extensively cultivated in India. Mango fruits and several processed preparations are exported to different countries. It contains high amounts of total solids, vitamins and minerals. Among the numerous varieties 'Safaida, Dashehari, Langra, Chaussa of U.P., Alphanso of Ratangiri, Badami of Mysore, Raspuri and Mulgoa of Tamilnadu and Karnataka are rich in total soluble solids and also in fermentable sugars (glucose, fructose and other sugars). In majority of mangoes, juice extraction is a problem and therefore pectinolytic enzymes are suitably added and the sugar level is raised to 20^{o} brix using cane sugar. Fermentation is done at 22^{o}C with 100 ppm of SO_2. Different varieties of mangoes results in products having varied taste and body.

v) Jamun wine

Jamun fruit is also native to Indian fruit and grown in every part of the country. Jamun fruits have therapeutic properties especially in diabetes and its products have wide acceptability everywhere. This fruit is also deficient in nitrogen, rich in pectin and hence amelioration with sugar (23^{o}Brix) diammonium hydrogen phosphate (0.2%), 0.25% pectinolytic enzyme and 150 ppm of SO_2 is required. The other factors remain the same as with other fruits (grapes etc.,) Popularization of the product is needed for indigenous and export purposes.

vi) Coconut and Palm wine or Toddy

Toddy is an alcoholic beverage produced from the sap of palm trees (*Acrocomia mexicana*) and coconut inflorescence sap. It is consumed in several parts of the country. The sap is collected in clay pots. The middle aged (fully grown) tree is selected and triangular or rectangular cut is made on the top of the tree and the earthen pot is hanged. The foamy sap flows and collects in the pot in the morning and evening. Freshly collected sap is sweet, relishing and invigorating. The fermentation starts as soon as sap starts collecting in the pot. The palm sap contains 10-12% sugar whereas coconut sap generally has about 15-18% sugars. Mostly toddy contains about 6-7% of ethanol. Natural fermentation takes place by the microorganisms present in the earthen pot. *Saccharomyces cerevisiae* is mostly present along with *Lactobacillus plantarum* and *Leuconostoc mesenteroides*. If fermented sap "toddy" is stored for longer time, acetic acid production ensues resulting in the spoilage of the product.

vii) Pomegranate and other fruit wines

Pomegranate (*Pumica grantum)* fruits are pressed as such to get astringency in the wine. Sugar is ameliorated in the pressed juice getting brix around 22-23^{o}B. Potassium metabisulphite is added to the must and it is inoculated with the starter culture (*Saccharomyces cerevisiae)* at the rate of 5%. Wine is produced in the California belt of the United States of America.

Litchi, Apricot, Pineapple, Date, Red Raspberry, Strawberry, Kiwi fruit, peach, Kinnow fruits, grape fruit, orange and plum, ber, guava and banana fruits can be used for wine production with certain modifications in the method of preparation. Majority of these fruits require enzymatic treatment to release the sugars and supplementation of juice with cane sugar and nitrogeneous salts. The other steps remain the same as followed for production of grape wine.

viii) Mead

Mead is a wine prepared from honey. The procedure followed for mead is the same which is employed for wine making from different types of fruits. Light coloured honey is preferred for this purpose. Honey is diluted to 22-23^{o}Brix, it is boiled and cooled and appropriately tannin, acid and diammonium hydrogen phosphate and SO_2 added to it. The must is inoculated with the active starter culture of *Saccharomyces cerevisiae* and fermentation is carried out at low temperatures. Mead is relished in European countries and several other parts of the world.

12.11 CHEMICAL COMPOSITION OF WINE

The chemical composition of the wine relates to its quality. There are several factors which influence the quality of wine. The most important factors affecting the quality have already been highlighted earlier. The typical wine contains ethyl alcohol, sugars, acids, higher alcohols, tannins, aldehydes, esters, amino acids, minerals, vitamins, anthocyanins, fatty acids, flavouring compounds and traces of methanol.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain how wine is produced from these fruits: apples, custard apples, pear, mango and jamun.

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2. Define toddy and explain its preparation.

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3. What do you know about mead?

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4. Do you know the typical chemical composition of wine?

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12.12 LET US SUM UP

Alcoholic beverages have been consumed all over the world since time-immemorial. Their (wine, beer, brandy, whisky, rum) consumption is gradually and streadily increasing in developed and developing countries equally inspite of several restrictions. Wine and beer if taken moderately, have health giving properties. When fruit juices (grapes, apple, pear etc.,) are allowed to spontaneous alcoholic fermentation or with addition of yeast culture, the sugar present in these get converted into ethanol and carbon dioxide and thus wine, cider, perry and if distilled, brandy are produced. The yeast, *Saccharomyces cerevisiae* or *Saccharomyces cerevisiae* var. *ellipsoideus* are primarily responsible for good alcoholic fermentation. The fermentation of fruit juices initially requires some oxygen for the growth of yeast and after its exclusion, ethanol and carbon dioxide are produced anaerobically. Several prefermentative and post fermentative practices are followed and when fermentation is complete, it is clarified with bentonite or gelatin. Maturation of wine (clarified and filtered fermented juice) is carried out in oak wood barrels and finally it is bottled in dark amber colour glass bottles. Apples, grapes, pears, mango, pomegranate, jamun can be utilized for wine production. Honey is used for mead production. Toddy another alcoholic beverage of India, has good invogirating and relishing effect if taken directly from the tree without any storage.

12.13 KEY WORDS

Wine	:	Alcoholic fermented juice of fruits
Cider	:	Wine from apples
Perry	:	Wine from pears
Mead	:	Wine from honey
Brandy	:	Distilled wine
Rum	:	From fermented molasses or canesugar
Whisky	:	Distillation of mash of malted grains
Beer	:	From malted barley
Toddy	:	Palm trees sap or coconut influorescence sap

12.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - The juice of grapes or any other fruits if allowed to ferment by natural fermentation or by addition of starter culture viz., yeast for some time and the resultant product after fermentation is wine.
   - Types of Wines are:
     - Champagne: foaming containing dissolved oxygen.
     - Sparkling wine: produced by injecting carbon dioxide into the wine.
     - Liqueur Wine: Sweet with higher content of alcohol.
     - Sherry: Fortified wine.
     - Port: Wine is stored in a wooden cask.
     - Vermouth: Flavoured wine
     - Brandy: Distilled wine
     - Cider: Produced from apple.
     - Perry: Produced from pears.

2. Your answer should include the following points:

   - The juice of grapes or some fruits contain high amounts of sugar mainly glucose and fructose sometimes 20-25%. The wine yeast present in the juice or added separately grows profusely and convert sugars into ethanol.

   - One mole of glucose gives rise two moles of ethanol and two moles of carbondioxide.

   - Usually 8-10% ethanol is obtained after fermentation.

3. Your answer should include the following points:

   - Grape juice or any other fruit juice.
   - The commercially used yeast strains for wine *Saccharomyces cerevisiae, Saccharomyces cerevisiae* var. *ellipsoideus*.

4. Your answer should include the following points:

   - Killer yeast/s infected with a virus that kills the wine yeast.

5. Your answer should include the following points:

   - *Saccharomyces cerevisiae* strains tolerate high levels of sugars in the fruit juices.

   - Tolerate high levels of ethanol.

   - Grow even at low pH.

   - Ferment fruit juices at low temperature.

   - Resistant to sulphur dioxide which checks the growth of bacteria, yeasts, moulds.

6. Your answer should include the following points:

   - Stemming, crushing and juice separation → clarification → adjustment of sugar level and acidity → fermentation

7. Your answer should include the following points:

   - The growth of wine yeast: *Saccharomyces cerevisiae* is checked due to the presence of Killer viruses and fermentation does not proceed well. A number of metabolites (chemicals) are released causing defective flavour and body of wine (Stuck Fermentation).

   - Clarifications and Stabilization, fining, centrifugation, filteration, removal of crystals, avoidance of haze formation maturation and bottling.

Check Your Progress Exercise 2

1. Your answer should include the following points:

    - Cider (A low alcoholic 4-6% ethanol) from apples.
    - Custard apple seeds and skin are removed and juice is supplemented with sugar and fermented.
    - Perry or pear wine from pears prepared by extra addition of nitrogen in the juice.
    - Juice extraction a big problem and therefore pectinolytic enzyme is used for the recovery of juice and which is supplemented with sugar and fermented (mango).
    - Jamun wine has therapeutic properties and good for diabetes patients.

2. Your answer should include the following points:

    - An alcoholic beverage produced from palm and coconut trees.
    - The sap is collected from the trees in the morning.
    - Freshly collected sap is sweet, relishing and invigorating.

3. Your answer should include the following points:

    - Prepared from honey.
    - Honey appropriately diluted and supplemented with tannic acid and phosphate and nitrogenous salts and fermented.

4. Your answer should include the following points:

    - Contains usually ethyl alcohol, sugar, acids, higher alcohols, tannins, aldehydes, esters, amino acids, minerals, vitamins, anthocyanins, fatty acids, flavouring compounds and traces of methanol.

12.15 SOME USEFUL BOOKS

1. Boulton, R.B., Singleton, V.L., Bisson, L.F., and Kunker, R.E. (1995) Principles and Practices of Wine Making. Chapman and Hall, New York.

2. Jackson, R. (1994) Wine Science: Principles and Applications. Academic Press, San Diego.

3. Zoecklein, B.W., Fuselang, K.C., Gump, B.H., and Nurry, F.S. (1995) Wine Analysis and Production. Chapman Hall, New York.

UNIT 13 TECHNOLOGICAL ASPECTS OF INDUSTRIAL PRODUCTION OF ALCOHOLIC BEVERAGES AND RELATED PRODUCTS

Structure

13.0 OBJECTIVES

After studying this unit, you should be able to:

- state the necessity of technology in alcoholic beverages production;
- describe the vats and tanks used for industrial production of alcoholic beverages;
- know how different types of beverages are manufactured and various steps involved in their production; and
- describe the method of vinegar production.

13.1 INTRODUCTION

In Unit 10, the industrial significance and necessity of fermentation and its relevance to the society have been highlighted in detail. Fermentation or production of wine, beer, cheese or bread is an art and has been practiced from time immemorial throughout the world. However, to meet the demand of the society, large scale operations are needed for any type of product. Therefore, for all the stages of commercial production, engineering involvement is warranted. The scientific knowledge on production of a product either developed in research laboratories or house-holds or cottage level, has to be developed in the form of a commercial process with the help of engineers, scientists and other experts. There are a number of commercial processes developed for alcoholic beverages and related products, and improvement in the quality and also cost reduction of the final products are made more often.

In brief, various aspects of industrial production of selected wines, distilled alcoholic beverages of fruit origin (Brandy) and vinegar are highlighted here.

13.2 FERMENTERS

In wine production, any non-porous, non-toxic vessel can be used as a fermenter. These are constructed of non-aromatic wood, cement, stainless steel or fiberglass. Only two types of fermenters: Vats and Tanks are employed for fermentation. The size of fermenter differs but most of the wineries use 20000 liters and above capacity vessels either open or closed. Sometimes smaller, barrels are employed in which fermentation and maturation both take place. All these are batch fermentation carried out for certain periods and then again recharged with must and restarted. Hydraulic press, filteration equipments and other machines and equipment are used for commercial production.

13.3 TECHNOLOGY FOR CIDER-MAKING

Cider is a low alcoholic drink prepared from the apple juice. Depending on the ethanol content, it is considered soft cider (1-5%) or hard cider (6-7%). In India, cider is not produced commercially. But the Indian varieties of apple cultivated in Jammu and Kashmir and Himanchal Pradesh e.g., Ambiri-Kashmiri, Red Delicious, Gold Pippin, Maharaji Apples and Golden Delicious can be utilized for cider making. A method for cider manufacture at a commercial scale is shown through flow diagram in Figure 13.1.

13.4 TECHNOLOGY OF SPARKLING CIDER

Sparkling cider is prepared by artificial carbonation. The secondary fermentation is carried out for 3-4 days at 21.0 ^{0}C. A protocol for carbonated cider is given in Figure 13.2.

13.5 TECHNOLOGY OF FORTIFIED WINES: VERMOUTH

Wines which are flavoured with herbs and spices and contain ethanol content in the range of 15-21%, are classed under 'Vermouth'. Both dry and sweet vermouth are prepared in European countries and relished in cocktails. It is prepared by making the wine and then extracting the spices and herbs mixture in wine and Brandy and blending with the wine produced and also adjusting the alcohol level. Grapes, apples apricots, mango, plum, even tamarind can also be used for vermouth production. Pear or similar types of fruit which are produced in abundance and commercially do not find much market, can be profitably used for vermouth manufacture. It is schematically illustrated in Figure 13.3.

13.6 TECHNOLOGY FOR BRANDY-MAKING (DISTILLED ALCOHOLIC BEVERAGES)

Brandy is defined as a distilled alcoholic beverage prepared from the distillation of wine or any fermented fruit juice. Usually brandy denotes the distilled wine of grapes whereas for other fruits it is prefixed with the fruit name e.g. apple brandy, plum brandy etc., Sometimes 'Cognac' word is also used for brandy. Cognac is produced in France. There are many varieties of wines mostly based on their place of manufacture.

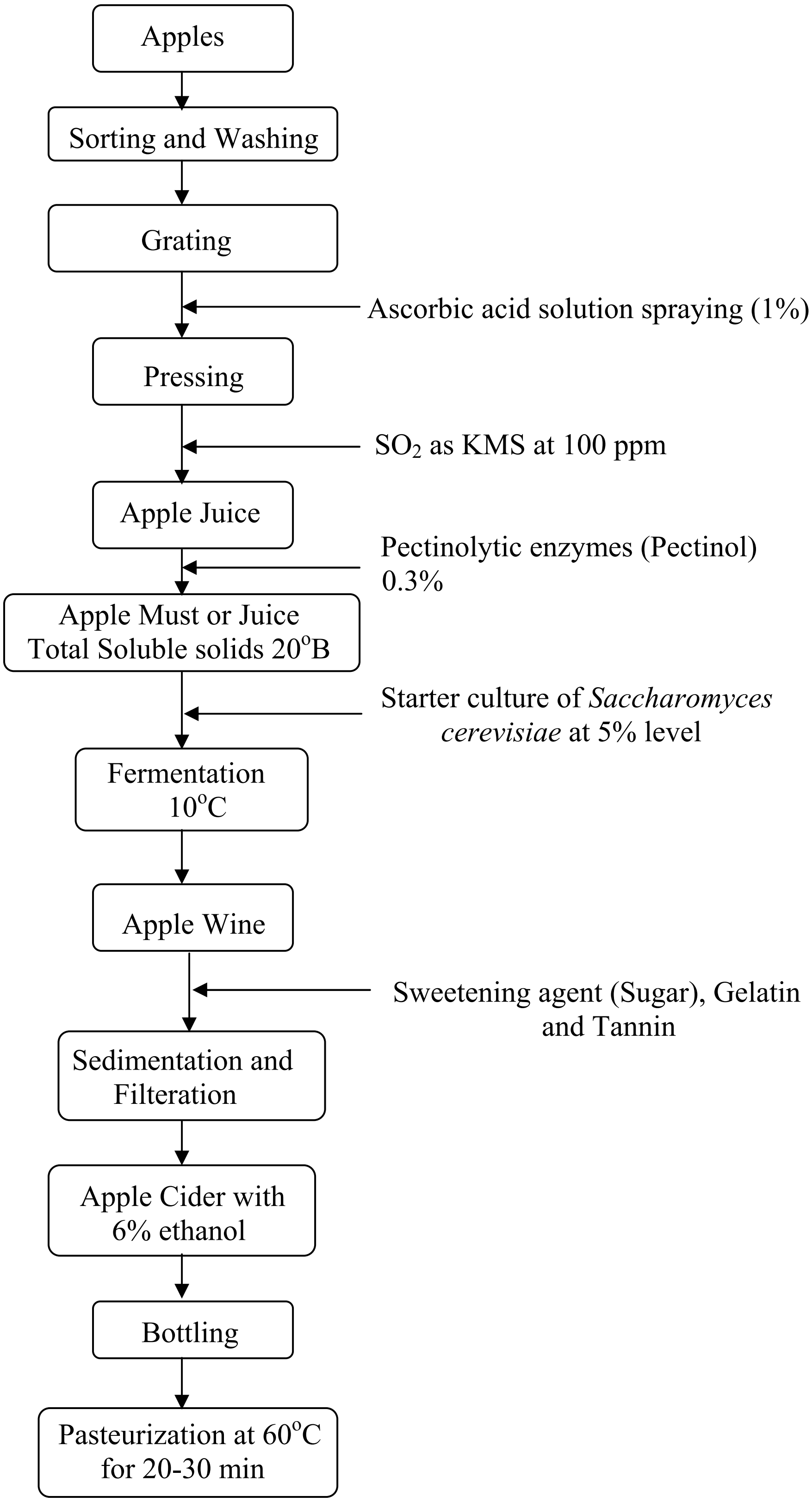

Figure 13.1: A protocol for cider production

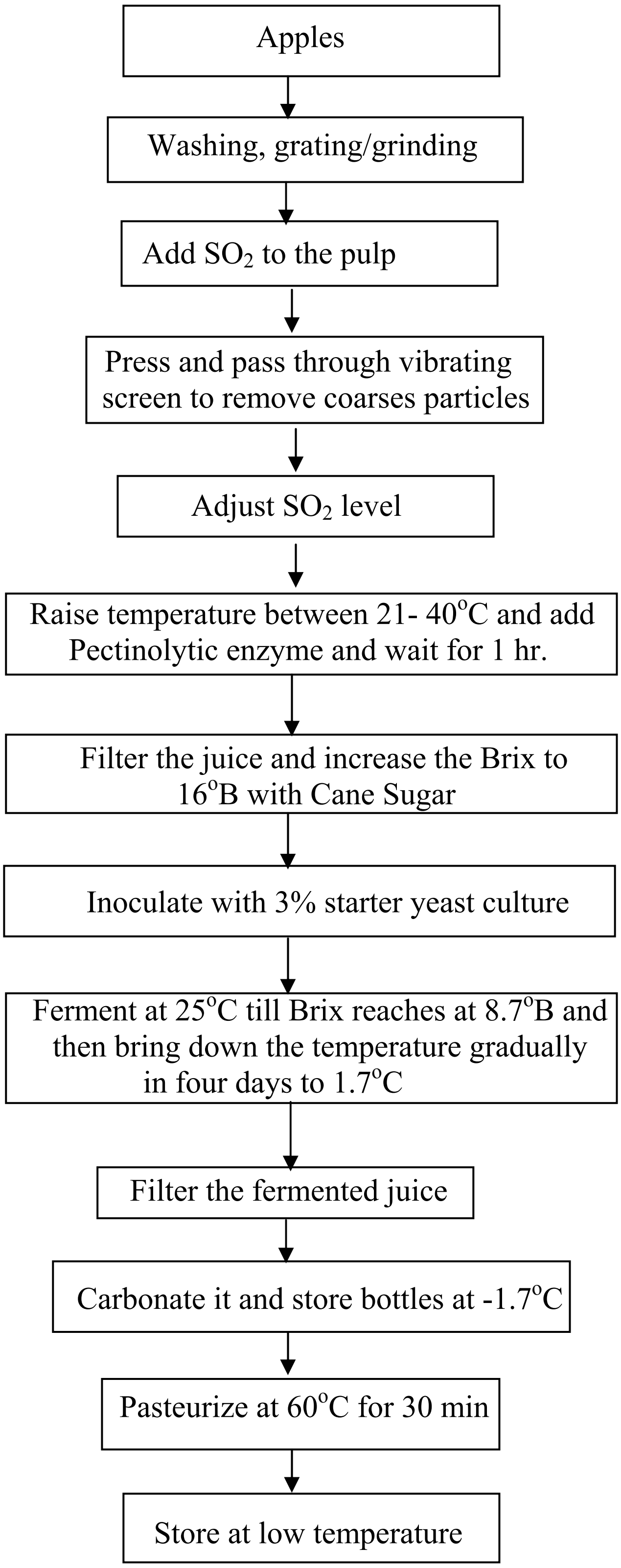

Figure 13.2: A protocol for carbonated cider production

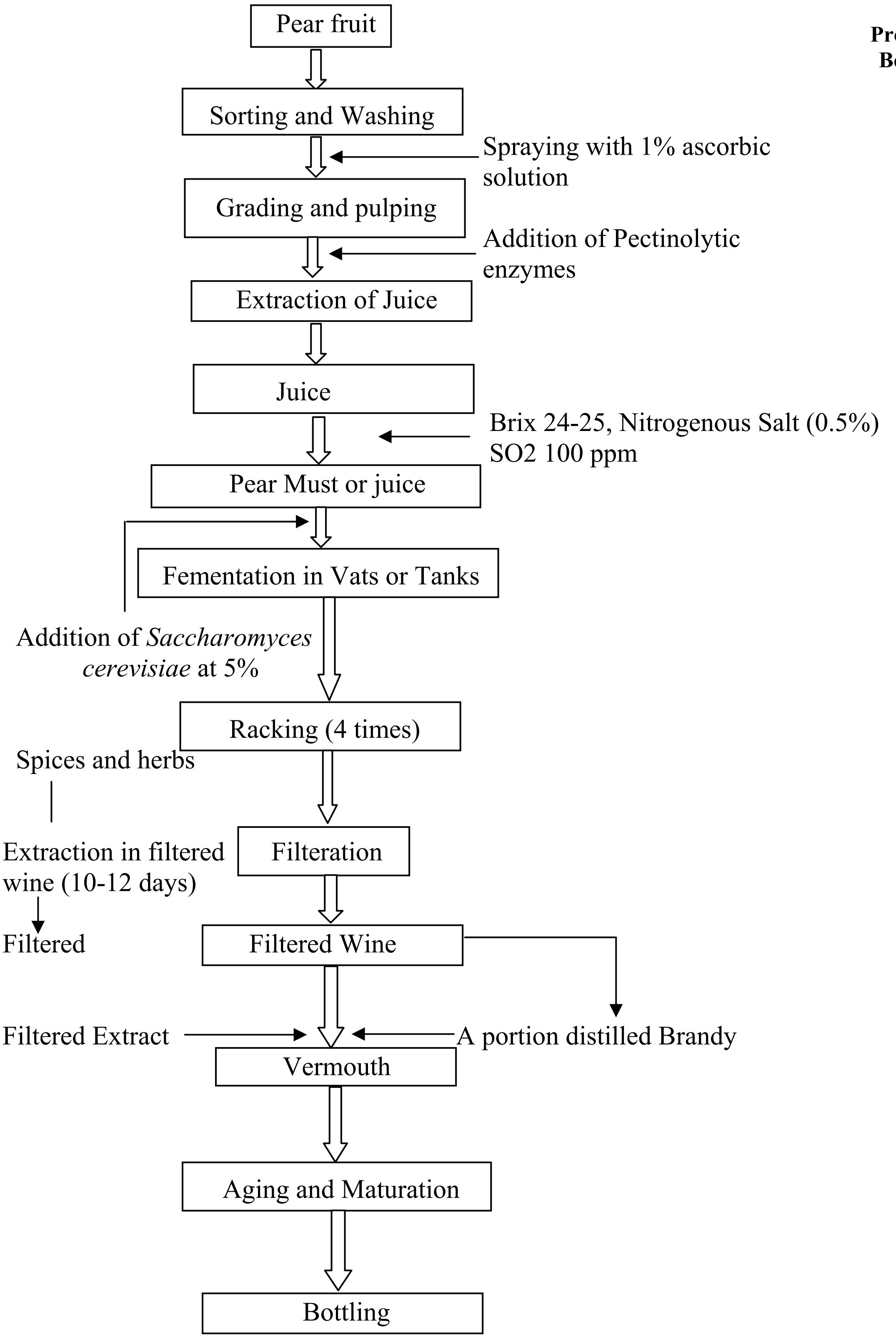

Figure 13.3: Manufacture of vermouth of pears

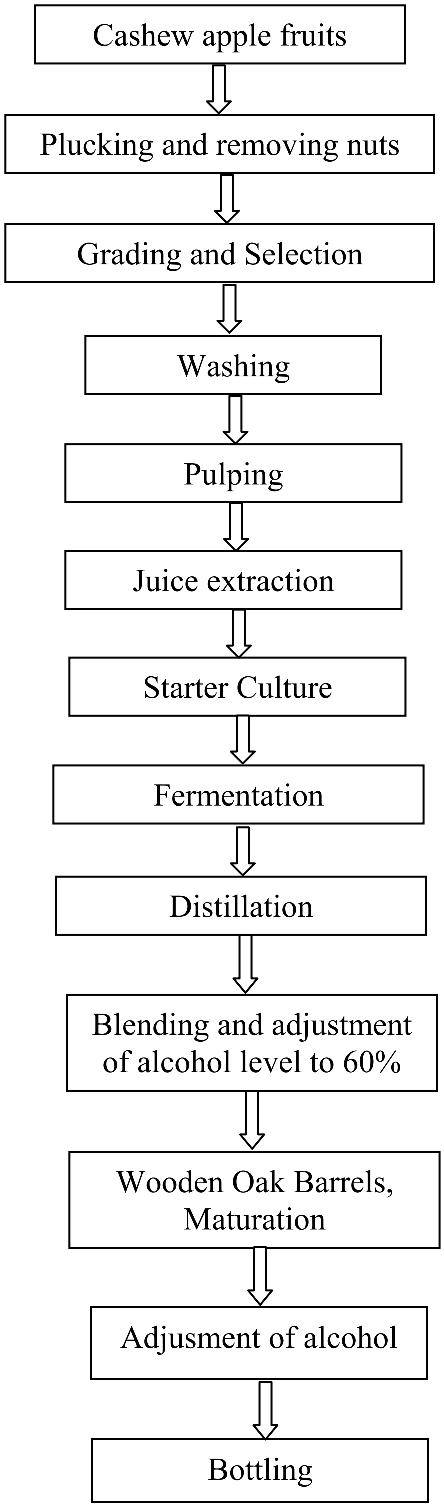

Figure 13.4: Manufacture of Feni from cashew apple

Like wines, brandy also contains many constituents. The major being ethyl alcohol (ethanol) along with fusel oil (higher alcohols e.g. n-propyl alcohol, isobutyl alcohol etc.,), traces of aldehydes esters (ethyl acetate) furfural and several other constituents. The method of base wine production for brandy is as employed for other wine manufacturing.

Distillation of fermented wine is carried out mostly in copper pot distillation unit but column stills (a vacuum distillation) is also adopted in some of the wineries. Distillation is carried out along with some fermented fruit materials and yeast cell biomass (lees). It is done in two steps. The first step results in about 28% of ethyl alcohol in the distillate whereas in the second stage of distillation of the distillate yields 70% of ethanol by volume. Brandy is stored in oak barrels. Some of the products are stored for several years e.g. 15 to 50 years and the quality improves during maturation. The final product has mostly 40-45% of ethyl alcohol by volume.

In the United States of America and several other countries, the strength of alcohol is measured in terms of proof. It denotes usually the twice the percent of ethyl alcohol content of a liquid at 60^{o}F.

13.7 TECHNOLOGY OF FENNY AND BRANDY OF CASHEW APPLE

Cashew apple is grown in large areas of the western coast of Karnataka, Goa and other states for cashew nuts. The nut is attached to the fleshy fruit and while processing, the fruit pulp is mostly wasted or a part is utilized for wine-making. It is rich in fermentable sugars and ascorbic acid. In Goa 'Kaju Feni' is quite popular. In Tanzania, Brazil and several other countries, alcoholic beverages are produced and used as a wine or occasionally distilled and consumed in the form of brandy. The word 'Feni' comes from the Konkani language, which means 'froth'. It is mostly produced at a cottage scale level. However, technical know-hows are available for commercial production of feni and brandy from it.

The cashew apple fruits are crushed and pulped and juice is extracted using extractors. The juice is left as such for spontaneous natural fermentation or inoculum of *Saccharmyces cerevisiae* at 5% is added, stirred and mixed evenly. Normally 2-3 days are taken for the fermentation. The feni is obtained by distilling the fermented juice with Urak* (2:1) containing 60% alcohol. Aging and maturation at 15^{o}C is carried out in oak wood barrels. After aging the product is marketed in bottles adjusting alcohol content to 42-43%.

The process of feni production is illustrated in Figure 13.4.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why is technology necessary for the production of alcoholic beverages?

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* Urak: Distilled feni containing 60% alcohol

2. What special type of fermenters needed for wine production?

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3. What are the important characteristics of sparkling cider and vermouth?

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4. Highlight the importance of brandy among alcoholic beverages.

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5. What do you mean by 'Fenny'? Write its method of production.

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13.8 TECHNOLOGY OF VINEGAR PRODUCTION BY FERMENTATION

Vinegar is consumed in almost every part of the world. Sugars mostly glucose, fructose and sucrose in appropriately diluted concentration are converted to ethyl alcohol by yeast/s and acetic acid producing bacteria convert this alcohol into ethanol by acetification thus producing vinegar. Vinegar contains at least 4% of acetic acid with some other solids. It is made from distilled alcohol prepared from cane molasses or other sugar sources. According to Indian Standards Vinegar should not contain arsenic, mineral acid, lead, copper, or colouring matter except caramel.

i) Method of Vinegar Preparation

Two distinct processes are involved in the preparation of vinegar:

a) Transformation of sugars of fruits or any sugary materials into alcohol by yeast anaerobically;

b) conversion by acetic acid producing bacteria of alcohol oxidatively in the presence of air into acetic acid.

$$\underset{\text{Fermentable Sugar}}{C_6H_{12}O_6} \xrightarrow{\text{Yeast}} \underset{\text{Ethylalcohol}}{2C_2H_5OH} + \underset{\text{Carbon dixoide}}{2CO_2}$$

$$\underset{\text{Ethyl alcohol+ Oxygen Sugar}}{2C_2H_5OH + 2O_2} \xrightarrow[\text{Producing bacteria}]{\text{Acetic acid}} \underset{\text{Acetic acid}}{2CH_3COOH} + \underset{\text{water}}{H_2O}$$

ii) Types of Vinegar

Cider Vinegar (apple juice)
Wine Vinegr (grape juice)
Spirit Vinegar (Dilute ethylalcohol from molasses)
Malt Vinegar (barley malt)
Orange, pineapple, banana, pear, peach, apricot, onion vinegars

iii) Process of Vinegar Preparation

There are a number of processes commercially used for vinegar production. The most commonly used are:

a) *Slow process:* The juice or sugary solution is filled into barrels and allowed to undergo alcoholic fermentation and acitification slowly. The mouth of the barrel or container is covered with a piece of cloth and placed in a damp and warm place. In about 5 to 6 months, the sugar solution turn into vinegar. This process is time-taking.

b) *Oreleans Slow Process:* The barrel used is filled three-fourth with the juice and two holes above the juice level on the either side of barrel are made in addition to top hole or mouth. These holes are tightly covered with cheese cloth to protect from insects and flies. The filled barrel is placed in a warm place (21-27^{o}C) and fermentation is allowed to take place. It takes about 3 months for complete fermentation. About three fourth of the fermented liquid (Vinegar) is withdrawn without making any hole in the top thick film of *Acetobacter* and again filled with the fresh juice.

c) *Quick Process:* It is known as the 'Generator' or the 'German' process. The generator is in the form of a cylinder 3.6 to 4.2 meters high and 1.2 to 1.5 meters in diameter. It has a false bottom and head, vent holes and sparge for discharging the liquor. It has three compartments. The central compartment is filled with beech wood shavings, corn cobs, pumice stone, straw to increase the surface area for the growth of acetic acid producing bacteria. The other distribution compartment is above 30 centimeters of the central compartment. It is separated by a partition perforated plate having a number of holes. A revolving sprinkler or a fitting trough is fitted in order to allow liquid to trickle slowly over the shavings of the Central Compartment. The third compartment is the bottom compartment separated from the central compartment by a perforated partition above 1.5 Meters the bottom of the generator.

Initially beech wood shavings are wetted with unpastuerized vinegar and then two parts of alcoholic juice and one part of vinegar is charged slowly to allow bacteria to colonize the shavings. When the generator becomes ready then alcoholic juice or liquid is passed through the generator on the top and acetified liquid (Vinegar) is collected having 3 to 4% acetic acid (volume). The air passage is cleaned from time to time. The optimum temperature is around 27-30^{o}C for this operation.

d) *Fringe Process:* The quick process has been improved by the addition of forced aeration and temperature control of trickling generators.

e) *Submerged Culture Process:* It has been tried for Vinegar production but *Acetobacter aceti* is quite sensitive to oxygen. Therefore, the aeration of the liquid is significantly important. However, it is 80 times faster oxidation of ethanol to acetic acid.

iii) Post-fermentation Process

a) *Aging:* Vinegar produced by quick process is kept for aging for about six months.

b) *Clarification:* Before bottling, vinegar is made sparkling clear.

c) *Pasteurization:* It is heated in an open vessel to about 60^{o}C and then cooled and bottled.

d) *Spoilage of Vinegar:* Lactic acid producing bacteria grow initially and spoil the vinegar. It should be fully avoided. Film yeast growing on the top also spoil the process of vinegar generation. Vinegar flies are well known to affect the quality of vinegar. Vinegar eels, louse and vinegar mites are the enemies of vinegar production. They should be completely eliminated.

At present a large proportion of our demand for vinegar is being met by synthetic vinegar. However, the fruit vinegar may be encouraged for consumption. People are not familiar with fruit vinegars and therefore, these have to be popularized highlighting their therapeutic importance in human health.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the importance of vinegar.

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2. What are the steps involved in vinegar generation and types of vinegar produced?

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3. List commercial processes used for Vinegar generation.

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13.9 LET US SUM UP

Production of exotic beverges in smaller quantities is an art but to meet the increasing demand of the people, large-scale operations at commercial scales are required. Therefore economically viable technologies are warranted for industrial production. All the beverages are commercially produced and marketed all over the world. Commercial vats or tanks with juice extractor and filteration or clarifier units are employed for these alcoholic beverages. Brandy manufacture requires a distillation unit along with the modern bottling plant. Vinegar is also a commercial fermentation produced throughout the world. There are a number of quick processes which take considerably shortertime for vinegar generation.

13.10 KEY WORDS

Vats and Tanks	:	Open or closed mouth vessels for wine fermentation.
Sparkling cider	:	Artificially carbonated cider.
Vermouth	:	Wine flavoured with herb and spices containing 15-21%, ethanol.
Brandy	:	Distilled wine or fermented fruit juice.
Fenny	:	Wine from cashew apple pulp.
Vinegar	:	Prepared from sugary materials by fermentation containing 4 grams of acetic acid/100 ml.

13.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - It is an art at house-hold or small scale production.
   - For Commercial production, large scale operation needed.
   - For large scale operations, engineering inputs needed for fermentation, filtration, maturation and bottling.

2. Your answer should include the following points:

   - Unlike other fermentations (antibiotic, citric acid), non porous and non-toxic vessels are used.
   - They are constructed from non-aromatic wood, cement, stainless steel or fibre glass.
   - Vats and tanks used for wine fermentation.

3. Your answer should include the following points:

   - Prepared by carbonation.
   - Secondary fermentation done at lower temperatures.
   - Wine which flavoured with herbs and spices and contain ethanol in the range of 15-21%: vermouth.

4. Your answer should include the following points:

   - Distilled wine or any fermented juice (brandy).
   - Mostly 40-45% ethanol volume (brandy).

5. Your answer should include the following points:

   - Produced from fleshy pulp
   - Sorting of pulp → extraction of juice → allowing spontaneous fermentation or addition of starter culture for 2-3 days → distillation of the fermented juice.
   - Distilled product contains 42% ethanol.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - A fermentation derived product, containing not less than 4 grams of acetic acid per 100 ml.
   - Prepared in the household in small quantities from sugarcane juice in India or cider or wine of fruits.

2. Your answer should include the following points:

   - Two distinct processes: the first being sugar fermentation to ethyl alcohol by *Saccharomyces cerevisiae* and the next being conversion of ethyl alcohol to acetic acid by *Acetobacter* spp.
   - Commercially available vinegar: Vinegar from jaggery, vinegar from cider, Barley malt vinegar.

3. Your answer should include the following points:

   - Slow process
   - Oreleans process
   - Quick process
   - Fringe process
   - Submerged process

13.12 SOME USEFUL BOOKS

1. Boulton, R.B., Singleton, V.L., Bisson, L.F., and Kunker, R.E. (1995) Principles and Practices of Wine Making. Chapman and Hall, New York.

2. Jackson, R. (1994) Wine Science: Principles and Applications. Academic Press, San Diego.

3. Zoecklein, B.W., Fuselang, K.C., Gump, B.H., and Nurry, F.S. (1995) Wine Analysis and Production. Chapman Hall, New York.

EXPERIMENT 1 DETERMINATION OF ACIDITY AND pH

Structure

1.1 INTRODUCTION

Acidity of foods is usually determined by acid, base titration using standard sodium hydroxide. The reaction being between a weak acid and a strong alkali, phenolphthalein is used as the end point colour indicator, which produces a faint pink colour around pH 8. For dark coloured solutions, alkali titration can be carried out to pH 8.1 using a pH meter.

pH of foods is determined using a pH meter having glass electrode and calomel electrode or a combination electrode.

Objectives

After studying and performing this experiment, you should be able to

- determine the acidity of food products by alkali titration; and
- determine the pH of the product using a pH meter.

1.2 EXPERIMENT 1a: DETERMINATION OF ACIDITY

1.2.1 Principle

Organic acids react with sodium hydroxide to form their corresponding sodium salts. The common organic acids are mono- carboxylic (acetic acid, lactic acid), dicarboxylic (malic and tartaric acids) and tri- carboxylic (citric acid) acids. The general reaction between an organic acid and sodium hydroxide is as follows.

$$R\text{–}(COOH)n + n\ NaOH = R\text{–}(COONa)n + n\ H_2O$$

By knowing the equivalent weight of the acid, the acid content can be calculated based on the alkali required for neutralization.

1.2.2 Requirements

Equipment and Apparatus

Chemical balance	
Conical flask – 250 ml	–3
Beaker – 100 ml	–1
Volumetric flask – 100 ml	–1
Burette – 10 ml	–1
Pipette – 5 and 10 ml	–1 each

Chemical and Reagents

Sodium hydroxide solution – 0.1 N

Phenolphthalein indicator – 0.1% in alcohol

1.2.3 Procedure

Acidity determination
Sample preparation

Thin Juices, RTS beverages etc.: Mix thoroughly and filter through previously washed and dried muslin cloth. Use 5-10 ml for titration.

Fresh fruits & vegetables, dried fruits, preserves, jams, marmalades pickles etc.: Pulp the material in a blender or mortar and mix thoroughly. Accurately weigh 10 to 20 g of the pulped material in a beaker, add about 50 ml distilled water and boil gently for 15 to 30 min replacing the water lost by evaporation. Cool, transfer to a volumetric flask (say 100 ml) and make up the volume. Filter through Whatman No.1 filter circle, if necessary.

Fruit pulps, squashes, syrups, cordial etc.: Weigh 10-20 g of the material, mix with distilled water, heat on steam bath to dissolve, cool and make up the volume in a volumetric flask (say 100 ml).

Pipette out suitable aliquot (5-10ml) of the prepared sample (quantity depending on the acidity of the sample) into a 250 ml. conical flask. Add about 50 ml of distilled water and few drops of phenolphthalein indicator. Titrate to light pink end point with 0.1 N NaOH solution. Products like juices and beverages may be directly weighed (5-10g) and transferred into 250 ml conical flask with about 50 ml distilled water and titrated.

1.2.4 Observations

Where samples are boiled with water and made up to volume:

Weight of sample	= W	= ---------- g
Volume made up to	= V_1	= ----------ml
Volume of aliquot taken for titration	= V_2	= ----------ml
Volume of NaOH required	= V_3	= ---------- ml
Normality of the NaOH solution	= 0.1	

Where sample is weighed and directly taken for titration:

Weight of sample	$= W_1$	= ---------- g
Volume of NaOH required	$= V_4$	= --------- ml
Normality of the NaOH solution	= 0.1	

1.2.5 Calculations

1000 ml 1N NaOH = One gram equivalent of organic acid.

Calculate the acidity in terms of the predominant acid present in the product. The equivalent weights of some common organic acids and the foods in which they are the major acids are given below. However, unless specifically required, it is customary to calculate the acidity of food materials as anhydrous citric acid.

Organic acid	**Equivalent Wt. (E.W.)**	**Foods**
Anhydrous citric acid	64	Citrus fruits
Malic acid	67	Raw mango, apple
Tartaric acid	75	Grapes, tamarind
Lactic acid	90	Milk foods
Acetic acid	60	Vinegar containing foods

For samples boiled with water and made up to volume:

$$\% \text{ acid} = \frac{\text{E.W. of acid} \times \text{Titer} \times \text{Normality of NaOH} \times \text{Volume made up} \times 100}{1000 \times \text{Aliquot taken} \times \text{Weight of sample}}$$

$$= \frac{\text{E.W. of acid} \times V_3 \times 0.1 \times V_1}{10 \times V_2 \times W}$$

For sample taken directly for acidity estimation:

$$\% \text{ acid} = \frac{\text{E.W. of acid} \times V_4 \times 0.1}{10 \times W_1}$$

For carbonate beverages, expel carbon dioxide by warming or just heating to boil, cool and then titrate.

1.2.6 Result

Acidity of the given product = Percent (w/w)

1.3 EXPERIMENT 1b: DETERMINATION OF pH

1.3.1 Principle

Acidity of any solution is dependant on the pH and in turn pH depends on the Hydrogen ion concentration of solution. pH can be calculated by the equation pH = negative logarthim of Hydrogen ion concentration i.e.,

$$pH = -\log (H^+)$$

1.3.2 Requirements

pH meter

Buffer solutions – pH 4.0, 7.0 and 9.0

1.3.3 Procedure

Sample preparation

Liquid samples are used as such for pH measurement. Solid and semi-solid materials have to be homogenized well before the measurement.

Procedure

The pH meter should be switched on for at least 30 min before taking measurements for stabilization. The pH meter is calibrated against standard buffers before measuring the pH of sample. pH meters are provided with operating instructions, which should be followed. Rinse the electrode(s) with water and wipe dry using a filter paper in between buffer and sample pH measurements.

1.3.4 Results

The pH of the sample is recorded usually to the first decimal place

1.4 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

EXPERIMENT 2 DETERMINATION OF MOISTURE

Structure

2.1 INTRODUCTION

Moisture content of vegetables and most of their products can be determined by drying the material in an air oven. A fairly high temperature of the order of 105^{0}C is required to remove the bound water in foods. However, at that temperature, foods containing appreciable proportion of sugars like fruit products decompose giving wrong results. Therefore, it is advisable to dry such products at lower temperature, such as $60\text{-}70^{0}$C, preferably in a vacuum oven.

Objectives

After performing this experiment, you should be able to:

- determine the moisture content of foods by air oven method; and
- determine the moisture content of sugary products by vacuum oven method.

2.2 EXPERIMENT

2.2.1 Principle

Moisture in foods exists both as free water and bound water. Bound water is more difficult to remove by heat. Therefore, the time required for complete removal of water from a food material varies. Hence drying has to be continued till constant weight is reached.

2.2.2 Requirements

Apparatus

Hot air oven (thermostatically controlled)	–1
Vacuum oven	–1
Chemical balance, 1 mg sensitivity	–1
Desiccator (with active desiccant)	–1

Moisture dishes with tight fitting lids –6

Aluminium dishes (7 cm. Dia.)
Sea sand (washed and ignited)
Glass rods

2.2.3 Procedure

a) Air oven method

Weigh accurately 5 g of the material in a dish previously dried and weighed. Place the dish along with lid in an electric air oven maintained at 70^{0}C in the case of fruits or their products, or 100^{0}C in the case of vegetables or their products. Cool the dish to room temperature in a desiccator and weigh with the lid on. Repeat the process of heating, cooling and weighing until the loss in weight between two successive weighings do not vary by more than 3-5 mg. For most of the samples 16-18 hr heating is sufficient. Record the lowest weight obtained.

b) Vacuum oven method

Place 20-25 g pure sea sand and a short glass rod in an aluminium dish having a tight fitting cover. Dry thoroughly and cool in a desiccator and weigh. Accurately weigh 5 g sample and transfer completely to the dish by rinsing with water. Mix well with the glass rod and heat on steam bath for partial drying. Transfer the dish to vacuum oven and dry the sample at 70^{0}C at a pressure not more than 100 mm Hg pressure. Cool in a desiccator and weigh. Repeat the process of drying, cooling and weighing until consecutive weighings made at intervals do not vary by more than 3 mg. Drying for 6 to 7 hr is generally found sufficient.

2.2.4 Observations

a) Air oven method

Weight of the weighing dish with lid = W_1 = ------- g

Weight of the dish with lid and material = W_2 = ------- g

Weight of the dish with lid and dried material = W_3 = ------- g

b) Vacuum oven method

Weight of the dish with sand and glass rod = W_1 = ------- g

Weight of the dish with glass rod and material = W_2 = ------- g

Weight of the dish with glass rod and dried material = W_3 = ------- g

2.2.5 Calculations

a) Air oven method

Weight of the material = (Weight of the dish with sample – weight of the dish)

= $(W_2 – W_1)$ = ------- g

Quantity of moisture in the material = (Weight of the material before drying – weight of the material after drying)

$$= (W_2 - W_3) = \text{-------}\ g$$

$$\text{Per cent moisture in the material} = \frac{\text{Quantity of moisture in the material}}{\text{Weight of the material}} \times 100$$

$$= \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100 = g/100g \text{ or } \%$$

b) Vacuum oven method

Weight of the material $= W_2 - W_1$ = ------- g

Quantity of moisture in the material $= W_2 - W_3$ = ------- g

$$\text{Per cent moisture in the material} = \frac{\text{Quantity of moisture in the material}}{\text{Weight of the material}} \times 100$$

$$= \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100 = g/100g$$

2.2.6 Results

Moisture content of the sample = ----------- Percent (%) by weight

2.3 PRECAUTIONS

The general precautions mentioned in the course ‘Introduction’ and those indicated in the experiments should be followed meticulously.

EXPERIMENT 3 DETERMINATION OF ASH AND ITS CHARACTERISTICS

Structure

3.1 INTRODUCTION

Ash content of foodstuffs represents inorganic residue remaining after destruction of organic matter. Acid- insoluble ash is a measure of sand and other silicious matter present. High ash content and/or low alkalinity of the ash in some cases could be due to the presence of adulterants.

Objectives

After studying and performing the experiments, you should be able to:

- determine the total ash content in
  - water-soluble ash;
  - acid-insoluble ash; and
  - the alkalinity of the ash in food products.

3.2 EXPERIMENT 3a: DETERMINATION OF TOTAL ASH

3.2.1 Principle

When a sample of a food material is ashed around 525^0C, the organic matter present is decomposed and expelled. The residue remaining is the mineral matter. The ash content is expressed as per cent weight by weight.

3.2.2 Requirements

Equipment and Apparatus

Silica dish (100ml cap.)
Chemical balance, 1mg sensitivity
Hot plate or burner
Muffle furnace
Desiccator (with an active desiccant)

Precautions

Do not transfer the hot silica dish directly from the muffle furnace to the desiccator. Cool to 100^oC and transfer to desiccator.

3.2.3 Procedure

Note the tare weight of three silica dishes. Accurately weigh 5 g of sample into each. Char the material carefully on a burner or hot plate and transfer the dishes to a muffle furnace and ash at a temperature of around 525^0C until a white ash is obtained. Moisten the ash in dishes with water. Dry on steam bath and on hot plate and re-ash at 525^0C. Cool in a desiccator and weigh. Reserve the ash in one dish for determination of water-soluble and water-insoluble ash, in second dish for acid-insoluble ash, and the ash in the third dish for determining alkalinity of ash.

3.2.4 Observations

Weight of silica dish $= W_1$ = ------- g

Weight of the silica dish with sample $= W_2$ = --- --- g

Weight of the silica dish with ash $= W_3$ =------- g

Calculation

$$\text{Total ash (\%) in the sample} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 = \frac{(W_3 - W_1)}{(W_2 - W_1)}$$

If the ash content has to be calculated on dry weight basis:

$$\textbf{Total ash content (\%) on dry weight basis} = \frac{(W_3 - W_1) \times 100}{(W_2 - W_1) \times (100 - M)}$$

Where, M is the moisture content (%) of the sample in percent by weight (determined as in experiment 2)

Expression of Results

Ash Content = % by weight or % by dry weight

3.3 EXPERIMENT 3b: DETERMINATION OF WATER-SOLUBLE AND WATER-INSOLUBLE ASH

3.3.1 Principle

When the total ash obtained from the above experiment is boiled in water, part of the ash dissolves (water-soluble ash) and part remains as insoluble ash. The insoluble ash can be estimated gravimetrically. The difference between total ash and water-insoluble ash gives water-soluble ash.

3.3.2 Requirements

Same as used for total ash

Reagents/chemicals

Whatman No. 41 filter circles
Red litmus paper

3.3.3 Procedure

Transfer the ash from one of the three silica dishes, with the aid of about 20 ml distilled water, into a beaker. Cover with a watch glass and boil for 5 min. Filter through an ashless filter paper (Whatman No. 41). Wash the entire residue with hot water until the filtrate no longer turns red litmus blue. (Reserve the entire filtrate for the determination of alkalinity). Dry the ashless paper with residue (water isolubles) in the same silica dish and transfer to muffle furnace and ignite at 525^{o}C for 2 hours. Cool in a desiccator and weigh.

3.3.4 Observations

Weight of silica dish No.1	= W_1 --- g
Weight of the silica dish with sample	= W_2 --- g
Weight of the silica dish with total ash	= W_3 --- g
Weight of the silica dish with water-insoluble ash	= W_4 --- g

3.3.5 Calculations

$$\text{Water-soluble ash (\%)} = \frac{\text{Total ash} - \text{water-insoluble ash}}{\text{Weight of sample}} \times 100$$

$$= \frac{(W_3 - W_1) - (W_4 - W_1)}{(W_2 - W_1)} \times 100 = \frac{(W_3 - W_4)}{(W_2 - W_1)} \times 100$$

$$\text{Water-soluble ash (\%) on dry wt.} = \frac{(W_3 - W_4) \times 100 \times 100}{(W_2 - W_1) \times (100\text{-}M)}$$

Where, M = Moisture % of sample.

3.3.6 Results

Water-soluble ash = % by weight on dry basis.

3.4 EXPERIMENT 3c: DETERMINATION OF ACID-INSOLUBLE ASH

3.4.1 Principle

Acid insoluble ash refers to the portion of ash, which does not dissolve in 1:2.5 HCl under the experimental conditions. This can be estimated either from the total ash (as obtained in Experiment 3a) or water-insoluble ash (as obtained in Experiment 3b).

Preparation of Sample

Use the ash of second disk obtained from the Experiment 3a.

3.4.2 Requirements

Apparatus

Same as used for total ash

Chemicals/ regents

Hydrochloric acid - dilute with distilled water (1: 2.5)
Whatman No. 41 filter circles
Blue litmus paper

Precautions

Do not inhale the vapours of Conc. Hydrochloric acid.

3.4.3 Procedure

To the ash of the second silica dish, add 25ml of hydrochloric acid, cover with a watch glass and boil gently for 5 min. Filter through ashless filter paper. Wash the entire residue with hot water (> 85^{o}C) until the filtrate no longer turns blue litmus paper red. Dry the ashless paper with the residue in the same dish and transfer to Muffle furnace and ignite at 525^{0}C for 2 hrs. Cool in a desiccator and weigh.

Alternatively, water-insoluble ash as obtained in Experiement 3b can also be used.

3.4.4 Observations

Weight of silica dish No. 2	= W_1	= --- g
Weight of silica dish with sample	= W_2	= --- g
Weight of the silica dish with ash insoluble in acid	= W_3	= --- g

3.4.5 Calculations

$$\text{Ash insoluble in acid (\%)} = \frac{\text{Acid-insoluble ash}}{\text{Weight of sample}} \times 100$$

$$= \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

$$\text{Ash insoluble in dilute HCl (\%) on dry wt.} = \frac{(W_3 - W_1) \times 100 \times 100}{(W_2 - W_1) \times (100 - M)}$$

Where, M = Moisture of the sample.

3.4.6 Results

Ash insoluble in dilute HCl = % by weight on dry basis.

3.5 EXPERIMENT 3d: DETERMINATION OF ALKALINITY OF ASH

3.5.1 Principle

Dissolving the total ash in a known volume of standard dilute HCl and titrating the excess acid with standard NaOH determine alkalinity of ash.

Preparation of Sample

Use the ash of the third dish obtained from Experiment 3a.

3.5.2 Requirements

Apparatus

Burette, 10 ml cap.
Conical flask, 250 ml

Chemicals and Reagents

Methyl orange, 0.1% in water
Hydrochloric acid – 0.1N
Sodium hydroxide – 0.1N

3.5.3 Procedure

To the ash in the third silica dish from Experiment 3a, add 10 ml of 0.1 N HCl. Dissolve by warming on a water bath, cool and titrate the excess acid with 0.1 N NaOH using methyl orange indicator. Alkalinity of ash is calculated as potassium carbonate (K_2CO_3).

3.5.4 Observations

Weight of empty dish No. 3	$= W_1$	= ----- g
Weight of dish with sample	$= W_2$	= ----- g
Weight of dish with ash	$= W_3$	= ----- g
Volume of 0.1 N HCl added to the ash	= A	= ----- ml
Titre value (ml 0.1 N NaOH)	= B	= -----ml
Normality of the acid	= N	

3.5.5 Calculations

One ml of 0.1 N HCl is equal to 0.00691 g of potassium carbonate

Therefore, g of potassium carbonate per g of ash =

$$\frac{\text{ml 0.1 HCl required to neutralize the alkalinity of the ash} \times 0.00691}{\text{Weight of the ash}}$$

$$= \frac{(A - B) \times 0.0061}{(W_3 - W_1)}$$

Alkalinity may also be expressed as number of ml of 0.1 N acid required to neutralize the ash from 100 g of the sample.

Alkalinity of ash from 100 g sample =

$$\frac{\text{ml 0.1 N HCl required}}{\text{Weight of sample}} \times 100 = \frac{(A - B) \times 100}{(W_2 - W_1)}$$

3.5.6 Results

Alkalinity of ash = g of potassium carbonate per g of ash, or ml 0.1 acid required to neutralize ash from 100g sample

3.6 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

Use a tongs with long handle for keeping and removing dishes from the muffle furnace.

EXPERIMENT 4 DETERMINATION OF REDUCING SUGARS, TOTAL REDUCING SUGARS, SUCROSE AND STARCH

Structure

4.1 INTRODUCTION

Several methods are available for estimation of reducing sugars. They include chemical, polarimetric and chromatographic methods. However, for routine analysis of food products, Lane and Eynon chemical method is most widely used. Non-reducing sugars and starch are first converted into reducing sugars for estimation.

Objectives

After studying and performing this experiment, you should be able to:

- prepare food products for estimation of reducing sugars, total sugars and starch; and
- determine reducing sugars, total sugars and starch in food products by Lane and Eynon method.

4.2 EXPERIMENT 4a: REDUCING SUGARS

4.2.1 Principle

Lane and Eynon method is based on the principle of reduction of Fehling's solution by reducing sugars. Fehling's solution is a mixture of copper sulphate and alkaline Rochelle salt (sodium potassium tartarate). Rochelle salt complexes with the cupric hydroxide formed in alkaline solution and prevent it from precipitation. Reducing sugars reduces the complexed cupric hydroxide to red, insoluble cuprous oxide under the experimental conditions. An oxidation-reduction indicator, usually methylene blue, detects the end point of the reaction.

The first step in the estimation of reducing sugars by Lane and Eynon method is the determination of Factor for Fehling's solution. Fehling factor is the quantity of invert sugar in grams required to completely reduce the Fehling's solution (usually 5 ml each of Fehling's A and B solutions).

Total sugars include reducing sugars and non-reducing di - and oligo-saccharides like sucrose, which on mild acid hydrolysis are converted into reducing sugars. Starch is hydrolysed by strong acids into glucose.

4.2.2 Requirements

Equipment and Apparatus

Chemical balance, 1mg sensitivity

Hot plate

Burette (50 ml cap.) with an off-set tip

Volumetric flask, 250 ml

Pipette, 5 ml and 25 ml

Conical flask, 250 ml

Weighing bottle

Funnel (small)

Whatman No. 1 filter circles

Chemicals and Reagents

Fehling's solution A: Dissolve 69.28 g copper sulphate ($CuSO_4.5H_2O$) in distilled water and dilute to 1000 ml. Filter and store in amber colour bottle.

Fehling's solution B: Dissolve 346 g Rochelle salt (Potassium sodium tartrate: KNa $C_4H_4O_6$. $4H_2O$) and 100 g NaOH in distilled water. Dilute to 1000 ml. Filter and store in amber colour bottle.

Neutral lead acetate solution: Prepare 20% neutral lead acetate solution.

Potassium oxalate solution: Prepare 10% potassium oxalate ($K_2C_2O_4$. H_2O) solution.

Methylene blue indicator: Prepare 1% methylene blue solution in distilled water.

4.2.3 Procedure

i) Standardization of the Fehling's Solution for Invert Sugar

Accurately weigh 4.75g of AR grade sucrose. Transfer to 500 ml volumetric flask with 50 ml distilled water. Add 5 ml conc. HCl and allow to stand for 24 hr. Neutralise the solution with NaOH using phenolphthalein as end point indicator and make up to volume. Mix well and transfer 25 ml to a 100 ml volmetric flask and make up to volume (1 ml = 2.5 mg of invert sugar). Transfer to a burette having an off-set tip and titrate against Fehling's solution as described below for sample.

Observations

Titre = V_1 = ------ ml

Calculations

$$\text{Factor for Fehling's solution (g of invert sugar)} = \frac{\text{Titre} \times 2.5}{1000}$$

$$= 0.0025 \times V_1 = \text{-------} \text{ g}$$

ii) Determination of Reducing Sugars

Preparation of sample

Weigh accurately 10-50 g sample as such (juices, beverages etc.) or homogenized sample (jams, preserves etc.) and transfer to 500 ml volumetric flask. Add about 100 ml water and neutralize with NaOH solution to phenolphthalein end point. Add 10 ml neutral lead acetate solution, shake and let stand for 10 min. Add potassium oxalate solution in small amounts until there is no further precipitation. Make up to volume, mix the solution well and filter through Whatman No. 1 filter circle. Transfer the filtrate to a 50 ml burette having an off-set tip.

Preliminary titration: Pipette out 5 ml each of Fehling A and B solutions into 250 ml conical flask. Mix and add about 10 ml water and a few pumice stone or glass beads. Dispense the sugar solution from the burette. Heat the solution to boiling. Add 3 drops of methylene blue indicator. Continue the addition of the sugar solution drop wise until the blue colour disappears to a brick-red end point. (The concentration of the sample solution should be such that the titre value is between 15 to 50 ml). Maintain a total boiling peiod of 3 min. Note down the titre value.

Final titration: Pipette out 5 ml each of Fehling A and B solutions into a 250 ml conical flask. Add sample solution about 0.05 to 1.0 ml less than titre value of the preliminary titration. Heat the flask to boiling. Add 3 drops of methylene blue indicator. Complete the titration within 1 min by adding 2 to 3 drops of sugar solution at a time, until the indicator is decolourized. At the end point, the boiling liquid assumes the brick red colour. Note down the titre value. Perform the titration in duplicate and take the average.

Note: i) Preliminary titration must be finished within 3 min.
ii) Conical flask should not be disturbed or removed from the burner before the titration is finished.

4.2.4 Observations

Weight of the sample = W = ------- g

Dilution volume for the sample = V_2 = ------ ml

Volume of clarified sample solution required for Fehling's reaction (titre) = V_3 = ------- ml

4.2.5 Calculations

Based on the factor for Fehling's solution, V_3 ml sample solution contains:

0.0025 V_1 g reducing sugar (as invert sugar)

$$\text{Therefore, \% Reducing Sugars in the sample} = \frac{0.0025 \times V_1 \times V_2 \times 100}{V_3 \times W}$$

$$= \frac{0.25 \times V_1 \times V_2}{V_3 \times W} = X\ \%$$

4.2.6 Results

Reducing sugars (as invert sugar) = % by wt.

4.3 EXPERIMENT 4b: TOTAL REDUCING SUGARS

4.3.1 Principle

Total reducing sugars represent reducing sugars and non-reducing di and oligo saccharides, which can be hydrolysed into reducing sugars with dilute acids.

4.3.2 Requirements

Same as for experiment 4a.

4.3.3 Procedure

Pipette an aliquot of 50 ml of the clarified, de-leaded filtrate to a 100 ml volumetric flask. Add 5 ml of conc. HCl and allow to stand at room temperature for 24 hours. Neutralise with conc. NaOH solution followed by 0.1N NaOH using phenolphthalein as end point indicator. Make up to volume and transfer to 50 ml burette having an off-set tip. Perform the titration against Fehling's solution similar to the procedure described for reducing sugars, and determine the total sugars as invert sugars.

4.3.4 Observations

Volume of the acid hydrolysed sample solution required for Fehling solution (titre) = V_4 = ------ ml

4.3.5 Calculations

Based on the factor for Fehling's solution, total reducing sugars in

V_4 ml = 0.0025 × V_1 g

As 50 ml of the clarified and de-leaded solution is diluted twice (50 ml to 100 ml) after hydrolysis, dilution volume of the sample = ($2 \times V_2$).

Therefore, % Total reducing sugars (as invert sugars) $= \dfrac{0.0025 \times V_1 \times 2 \times V_2 \times 100}{V_4 \times W}$

$$= \frac{0.5 \times V_1 \times V_2}{V_4 \times W} = Y\ \%$$

Total reducing sugars comprises of reducing sugars and non-reducing sugars, which can be hydrolysed into reducing sugars under the experimental conditions. This non-reducing sugar is usually expressed in terms of sucrose.

As 0.95 g sucrose on hydrolysis yields 1 g invert sugar (glucose + fructose):

% Sucrose in the sample = (Total reducing sugars – % Reducing sugars originally present) × 0.95

$$= (Y - X) \times 0.95$$

[% Total sugars = (% Reducing sugars + % Sucrose)]

4.3.6 Results

Sucrose content in the sample = % by weight

4.4 EXPERIMENT 4c: STARCH

4.4.1 Principle

Starch is hydrolysed to glucose with strong acid and the reducing sugar formed is estimated by Lane and Eynon method. Sample containing sugars are washed to free it from them before hydrolysing the starch. Traces of lipids present are also washed off with petroleum ether before hydrolysing the starch.

4.4.2 Requirements

500 ml conical flask with std. joint to fix Liebig condenser
Petroleum ether
Alcohol – 95%and 50%
10% Alpha naphthol solution in alcohol
Sulphuric acid- conc.
Stainless steel vessel (5 lit. cap.), 10” dia.
Test tube – 10 ml
Centrifuge

4.4.3 Procedure

For samples containing sugars and less starch, to weighed quantity (50-100 g), add a little of water and heat to 60°C. Allow to stand for some time to obtain a solution of starch. Add about 100 ml 95% alcohol and centrifuge (2000 rpm, 10 min.) to settle the precipitate. Filter and wash the residue with about 50% alcohol until the filtrate gives no positive test for sugars. To test for sugars, to a few ml of the filtrate in a test tube, add a drop of 10% alpha naphthol reagent. Allow 1 ml of pure conc. H_2SO_4 to flow slowly down the side of the test tube so as to form a layer beneath the aqueous solution. If sugars are present, a red ring will appear within a few seconds at the junction of the two layers. Use the 50% alcohol-washed and dried precipitate for starch hydrolysis as below.

For starchy materials, weigh accurately about 2-5 g sample in a beaker. Add ether and stir well. Allow to settle and decant the ether portion and discard. Repeat the step 3-4 times and dry the sample.

Transfer the prepared sample to a conical flask and add 200 ml water and 20 ml conc. HCl. Place the flask in a steel vessel filled with 2/3rds volume of water. Connect the flask to a water-circulating condenser. Heat the vessel and allow the water to boil for exactly 2 hr. Shake the digestion flask intermittently during boiling. Remove the flask and cool the contents. Transfer the contents to a 500 ml volumetric flask and neutralise with sodium hydroxide. Filter through Whatman No. 1 filter circle. From the filtrate determine the reducing sugar content using Lane and Eynon titrimetric procedure.

4.4.4 Observations

Weight of sample	= W	= ------ g
Hydrolysed sample volume made up to:	= V_5	= ----- ml
Titre	= V_6	= ----- ml

4.4.5 Calculations

Based on the factor for Fehling's solution, reducing sugar content of V_6 ml of the hydrolysed starch solution = $0.0025 \times V_1$ g

The theoretical yield of reducing sugars (glucose) on complete hydrolysis of starch is: 0.90 g starch = 1 g glucose. However, for practical purposes, the currently accepted factor is: 0.925 g starch = 1 g glucose.

$$\text{Therefore, \% Starch content of the sample} = \frac{0.0025 \times V_1 \times V_5 \times 100 \times 0.925}{V_6 \times W}$$

4.4.6 Results

Starch content of the sample = per cent by weight.

4.5 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

EXPERIMENT 5 DETERMINATION OF CRUDE FIBRE

Structure

5.1 INTRODUCTION

Crude fibre is the organic residue, which remains after the food sample has been treated with petroleum ether, boiling dilute sulphuric acid, dilute sodium hydroxide solution and alcohol under the standardized conditions. The crude fibre consists largely of cellulose together with a little lignin.

Objectives

After studying and performing this experiment, you should be able to:

- estimate the crude fibre content of food materials and products.

5.2 EXPERIMENT: DETERMINATION OF CRUDE FIBRE

5.2.1 Principle

By treating a food material successively with petroleum ether, sulphuric acid and sodium hydroxide, all the lipids, carbohydrates etc. are removed/ hydrolysed leaving only the crude fibre along with some insoluble mineral matter. The insoluble residue is freed of the soluble materials by water washing and filtration, and ashed. The difference in weight of the alcohol washed residue (dried) and the ash give the weight of true crude fibre.

5.2.2 Requirements

Equipment and Apparatus

Chemical balance, 1 mg sensitivity

Air oven (maintained at 100 ± 2 ^{0}C)

Muffle furnace (525 ± 5°C)

Hot plate

Digestion flask – 500ml

Water-jacketed condenser

Desiccator

Sintered glass crucible (porosity 100-160 µm) or

Linen cloth having 45 threads / inch.

Chemicals

0.255 N Sulphuric acid solution – 1.25 g H_2SO_4/100 ml

0.313 N Sodium hydroxide solution – 1.25 g NaOH/100 ml, free or nearly so from sodium carbonate.

Petroleum ether

Ethyl alcohol

5.2.3 Procedure

Grind the sample in a grinder to pass through No. 30 mesh sieve. Mix well to get a homogenous sample. Extract 2 g sample with ether and transfer residue to the digestion flask. Add 200ml hot sulphuric acid (1.25%) and connect to the reflex condenser and heat (it is essential that the solution boils within one minute). Boiling is continued briskly for exactly 30 min. Rotate flask frequently until sample at sides is thoroughly wetted. Take care to keep material from remaining on the sides of the flask. Immediately filter through linen cloth and wash with boiling water until the washings are acid free. Wash the residue back into the flask with 200ml hot sodium hydroxide solution (1.25%). Connect flask to reflux condenser and boil briskly exactly for 30 min. Remove the flask immediately and filter the contents through sintered crucible. Carefully transfer the entire residue to the flask with hot water. Wash the residue in the sintered crucible with hot water until the filtrate is alkali free. Wash with ethyl alcohol followed by ether. Then, dry at 100^0C to constant weight (W_1). Transfer the sintered crucible to a muffle furnace at 525^0C and ash the material. Cool and weigh (W_2). The loss in weight represents crude fibre.

5.2.4 Observations

Weight of the sample taken for ether extraction = W = ---- g

Weight of the sample after acid and alkali treatment along with sintered crucible = W_1 = -----g

Weight of residue after ashing along with the sintered crucible = W_2 ---- g

5.2.5 Calculations

Weight of crude fibre in the sample = Weight of acid and alkali digested residue minus weight of the ash = $W_1 – W_2$

$$\text{Crude fibre \%} = \frac{(W_1 - W_2) \times 100}{W}$$

$$\text{Crude fibre \% on dry wt.} = \frac{(W_1 - W_2) \times 100 \times 100}{W \times (100 - M)}$$

Where, M = % moisture content of the sample.

5.2.6 Results

Crude fibre = % by wt. on dry basis

5.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

EXPERIMENT 6 DETERMINATION OF ALCOHOL BY SPECIFIC GRAVITY METHOD

Structure

6.1 INTRODUCTION

Alcohol content in alcoholic beverages like wines, beer, distilled spirits etc. is routinely determined. Good quality fruit juices contain practically no alcohol. The trace amount measured by distillation method is due to the other volatile components. However, if over ripe fruits are used for juice production or the juice has undergone some fermentation due to improper handling of the juice, the alcohol content will increase. Therefore, high alcohol content in fruit juices is an indication of poor quality.

Objectives

After studying and performing this experiment, you should be able to:

- carry out distillation of beverages to recover alcohol; and
- determine alcohol content by specific gravity method.

6.2 EXPERIMENT: DETERMINATION OF ALCOHOL

6.2.1 Principle

Alcohol present in fruit juices and beverages can be distilled out completely along with water. Based on the differences in specific gravities of water and alcohol, the alcohol content can be determined.

6.2.2 Requirements

Apparatus and Reagents

Alcohol distillation apparatus

Specific gravity bottle, 50 ml capacity

Electronic balance, 0.1 mg sensitivity

Volumetric flask

Thermostatically controlled water bath

Chemicals

Bromothymol blue indicator (1% solution)

0.1 N Sodium hydroxide solution

6.2.3 Procedure

Expel CO_2 from the sample if present by shaking thoroughly. Fill the sample in a 100 ml volumetric flask to just below the mark and immerse the flask in a water bath maintained at a constant temperature (usually 25^0C). After the sample has attained the bath temperature, make up the volume with more sample. Transfer the contents of the volumetric flask to the distillation flask (300 – 500 ml round bottomed flask) using 10 – 15 ml distilled water to rinse the flask thrice. Add a few drops of bromothymol blue indicator and titrate with 0.1 N NaOH to a distinctive blue colour to neutralize any volatile acids present. Connect the condenser to the distillation flash and let the tip of the condenser dip into about 10 ml of distilled water contained in the original 100 ml volumetric flask. Distil and collect the distillate almost to the 100 ml mark. Place volumetric flask in the water bath to attain the same temperature as was done for the sample and make up the volume with distilled water.

Weigh a specific gravity bottle accurately. Fill the bottle with the alcohol distillate, insert the stopper, remove the spill-over solution with a tissue paper and weigh. Transfer the solution back to the volumetric flask, clean and fill the bottle with distilled water and weigh as done for the sample. Calculate the specific gravity of the sample distillate and read the alcohol percentage from table of specific gravity vs. alcohol % by volume.

6.2.4 Observations

Weight of the empty sp. gravity bottle	= W_1	= ----- g
------ do ---- with sample distillate	= W_2	= ----- g
------ do ---- with distilled water	= W_3	= ----- g

6.2.5 Calculations

Specific gravity of the sample distillate =

$$\frac{\text{Weight of a known volume of sample}}{\text{Weight of same volume of distilled water}} = \frac{(W_2 - W_1)}{(W_3 - W_1)}$$

Determine ethyl alcohol content (per cent by volume) corresponding to the specific gravity by using the following Table

6.2.6 Results

Alcohol content of sample = percent (v/v).

Ethyl alcohol content (v/v) at 15.56°C (60°F) corresponding to specific gravity

Apparent sp.gr	Alcohol conc. %	Apparent sp.gr	Alcohol conc. %
0.9992	0.53	0.9813	14.05
0.9990	0.66	0.9801	15.06
0.9985	1.00	0.9790	16.00
0.9976	1.60	0.9778	17.04
0.9970	2.01	0.9767	18.00
0.9955	3.04	0.9755	19.06
0.9941	4.02	0.9744	20.03
0.9927	5.02	0.9622	30.02
0.9913	6.06	0.9472	40.05
0.9900	7.05	0.9288	50.04
0.9887	8.06	0.9075	60.03
0.9875	9.01	0.8837	70.02
0.9862	10.05	0.9572	80.02
0.9850	11.00	0.8270	90.02
0.9837	12.06	0.7981	100.00
0.9825	13.04		

6.3 PRECAUTIONS

The general precautions mentioned in the course ‘Introduction’ and those indicated in the experiments should be followed meticulously.

Avoid holding the body of the specific gravity bottle, especially after filling solutions. This will cause expansion of the solution, which will flow out resulting in wrong results. Hold the bottle at the neck.

EXPERIMENT 7 DETECTION AND DETERMINATION OF SYNTHETIC COLOURS

Structure

7.1 INTRODUCTION

Only eight synthetic coal-tar dyes are permitted under PFA for addition to food products. PFA also specifies the foods to which such colours should not be added as well as the maximum permissible limits (0.2 g per kg) of the colours in the foods in which the colours are permitted.

Among the food additives, synthetic colours are viewed with extreme caution due to their potential toxicity to the human system. Therefore, identification and quantification of synthetic food colours in foods is very important.

Objectives

After studying and performing this experiment, you should be able to:

- identify coal-tar dyes added to foods; and
- determine the concentration of the colour(s) in the food product.

7.2 EXPERIMENT

7.2.1 Principle

Synthetic acidic colour(s) is dyed on to wool in acidic medium and extracted (stripped) from the wool into aqueous alkaline medium. The extracted colour(s) is developed (separated) by paper chromatography along with standard dyes using a suitable solvent system. Comparing their Rf values with that of standard colours identifies the sample colours. Quantification of the colours is done by spectrophotometry.

7.2.2 Requirements

Instruments and Apparatus

Chemical balance

Spectrophotometer with 1 cm quarts cells

Measuring cylinders – 25 ml, 50 ml

Volumetric flasks – 50 ml, 100 ml

Conical flasks – 100 ml, 250 ml

Beakers – 100 ml

Wool

Chromatographic chamber

Thin layer chromatogrphic plates

Chromatography column – glass column with tapered end (2.1 × 45 cm) filled with alumina

Glass capillaries

Chemicals

Butanol: Acetic acid: Water (BAW) solvent: 20: 5: 12 (v/v/v)

Liquor ammonia

Acetic acid

Sodium citrate

pH paper strips

Alumina (acidic aluminium oxide)

Standard reference colours

White knitting wool: Successively boiled in dilute ammonia, washed in water, boiled in dilute acetic acid, again washed in water and dried.

Whatman No. 1 and No.3 Chromatographic paper, 20 × 20 cm

7.2.3 Procedure

I. Detection

1. *Wool dyeing:* Take 50 ml or 50 g of the sample, add enough distilled water and prepare a free-flowing solution. Add 4 to5 pieces of 5 cm long woollen thread to the solution and acidify the solution with acetic acid (few ml, check with pH paper) and boil for 10 to 20 minutes. Take out the pieces of wool from the solution and wash in water. Transfer the woollen pieces to a beaker and strip (extract) the colour by boiling with dilute ammonia (1 part of liquor ammonia + 50 parts of distilled water) and remove the wool. Make the extracted solution acidic with acetic acid. Immerse fresh small pieces of wool in the extract and boil for 10 min. If the wool is not dyed then report absence of added artificial colouring matter. If the wool is dyed, it indicates the presence of a coal-tar dye. Wash the wool with water and again strip the colour in boiling ammonia solution, filter; evaporate to a small volume in a beaker for chromatography. The above method is not suited for basic dyes.

   For basic dyes reverse the method i.e. dye the wool first in dilute ammonia and then strip in acetic acid. At present, all the permitted water-soluble coal-tar dyes are acidic and hence an indication of the presence of basic dye at this stage indicates presence of unpermitted colour.

2. *Paper chromatography:* Draw a horizontal line 2.5 cm from base of the filter paper (Whatman No.1). Spot the extracted colour solution on the line along with standard colour (dye) solutions and develop the chromatogram using one of the most effective solvent system viz. "BAW" – Butanol : Acetic acid : Water (20:5:12). When solvent front runs to a height of about 15 cm, remove the chromatogram and dry. Compare the sample Rf with the standard Rf, and identify the colour.

$$\text{Rf value} = \frac{\text{Distance moved by the solute (colour)}}{\text{Distance moved by the mobile phase (solvent)}}$$

Standard colour spot(s) corresponding to the sample colour(s) = -------- name of the standard colour(s)

II. Quantification

Samples containing single colour

Weigh about 5-10 g sample. Add about 25 ml water and mix well. Pass the solution through a column containing acidic aluminium oxide. Wash the column with water to remove sugars and natural colours. Elute the adsorbed colour with 1% ammonia. Transfer the eluate to a volumetric flask (25 ml) and make up to volume with 0.1 N HCl. Determine the absorbance of the dye solution at the absorption maxima (λ max).

Samples containing mixture of colours

Elute the mixture of colours by column chromatography and make up to a known volume (5 to 10 ml). Streak an aliquot of 0.5 ml on Whatman No. 3 paper and develop the chromatogram using the solvent system. Dry the paper and cut out the individual colour bands and elute with 0.1 N HCl. Make up to a known volume and determine the absorbance of each of the dye solutions at their absorption maxima.

7.2.4 Observations

a) Sample containing single colour

Weight of the sample	= W = ------ g
Volume of column eluate made up	= V = ------ ml
Absorbance of the solution	= A ----------
$E^{1\%}_{1cm}$ of the dye at λ max	= E ----------

b) Sample containing mixture of colours

Weight of the sample	= W_1= ------ g
Volume of column eluate made up	= V_1 = ------- ml
Volume of the eluate streaked on chromatographic paper	= V_2 = ----- ml
Volume of made up HCl extract of each colour band	= V_3 = ----- ml
Absorbance of the made up HCl extracts	= A1, A2, A3 ---- An
$E^{1\%}_{1cm}$ of the dye	= E1, E2, E3 ----- En

7.2.5 Calculations

a) Dye content of the product (%) = $\dfrac{\text{Absorbance} \times \text{Volume of eluate made up} \times 100}{E^{1\%}_{1cm} \text{ of the dye} \times 100 \times \text{Wt. of sample}}$

$$= \frac{A \times V}{E \times W}$$

Therefore, dye content of the product (ppm) = $\dfrac{A \times V}{E \times W} \times 10{,}000$

b) Calculate the content of each dye separately. Here, calculation for the dye having absorbance = A1 and $E^{1\%}_{1cm}$ = E1 is given as an example.

Content of the dye in the product (ppm) = $\dfrac{A \times V_3 \times V_1 \times 10{,}000}{E \times V_2 \times W_1}$

$E^{1\%}_{1cm}$ for standard permitted food colours are given below.

$E^{1\%}_{1cm}$ = Extinction (Absorbance) of 1 % solution of a dye at its absorption maxima when measured in a 1 cm cell.

Colour	λ_{max} (nm)	$E^{1\%}_{1cm}$
Tartrazine	426	527
Sunset Yellow FCF	480	551
Ponceau 4R	505	431
Carmoisine	515	545
Erythrosine	526	1154
Indigo carmine	610	489
Fast Green FCF	625	1560
Brilliant Blue FCF	629	1637

7.2.6 Results

The quantity of added colour is expressed in parts per million (ppm) or mg/kg.

7.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

While handling the dye solutions care should be taken to prevent it from getting them into the mouth because some of them may be unpermitted and harmful.

The spectrophotometer is a very costly instrument. Use it only after carefully understanding its operation. Similarly, the silica cells used are very costly and brittle. Handle them with utmost care. The silica cells should be wiped only with soft tissue to prevent scratching the transparent glass surface.

UNIT 1 UNIT OPERATIONS

Structure

1.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- comprehend the use and utility of food engineering in the food processing sector;
- know various systems of units and dimensions of quantities used in food engineering; and
- understand the principles of thermal processing and effective utilization of freezing, evaporation and dehydration in food processing and preservation.

1.1 INTRODUCTION

Most food processing operations are designed to extend the shelf-life of the product by reducing or eliminating microbial activity. This general objective implies that the processing operation meets the minimum requirement of ensuring any human health safety concerns associated with microbial activity. It must be acknowledged that most, if not all, food processing operations will influence the physical and sensory characteristics of the product. It is now a common practice within the food industry to utilize processing operations as an approach to enhance the physical and sensory characteristics of food products for better consumer acceptance.

The aims of the food processing are fourfold:

1. To extend the period during which a food remains wholesome (the shelf life) by preservation techniques which inhibit microbiological or biochemical changes and thus allow greater time for distribution and home storage;

2. To increase variety in the diet by providing a range of attractive flavours, colours, aromas and textures in food (collectively known as *eating, sensory* or *organoleptic quality);* a related aim is to change the form of the food to allow further processing (for example the pulping of fruits);

3. To provide the nutrients required for health (termed as *nutritional quality*);

4. To generate income for the entrepreneur or manufacturing company.

All the food processing activities involve a combination of procedures to achieve the intended changes to the raw materials. These procedures are conventionally categorized as *unit operations,* each of which has a specific, identifiable and predictable effect on a food item. A number of unit operations, same or different in nature form a process. The combination and sequence of operations, same or different in nature determines the nature of the final product.

In this unit, we will take up some basic concepts and unit operations that are important in food engineering.

1.2 DIMENSIONS

In food processing, we will talk of several parameters/quantities that make sense of when their dimensions and units are known. A dimension defines a physical entity, which can be observed and / or measured, quantitatively. For example, time, length, area, volume, mass, force, temperature, and energy are all considered dimensions. A unit expresses the quantitative value of a dimension. For example, length may be measured as metres, centimetres, or millimetres. According to the selected unit, the magnitude would be different.

Primary dimensions, such as length, time, temperature, mass, and force, express a physical entity. Secondary dimensions involve a combination of primary dimensions (e.g., volume is length cubed; velocity is distance divided by time).

It is necessary for equations to be dimensionally consistent. Thus, if the dimension of the left-hand side of an equation is “length,” it is necessary that the dimension of the right-hand side is also “length” otherwise the equation is inconsistent. In solving numerical problems, it is always useful to write units for each of the dimensional quantities within the equations. This practice is helpful to avoid mistakes in calculations.

1.3 ENGINEERING UNITS

Physical quantities are measured using a wide variety of unit systems. The most common systems are the Imperial (English) system; the centimeter, gram, second (CGS) system; and the meter, kilogram, second (MKS) system. The use of these systems, along with a myriad of symbols to designate units, has often caused considerable confusion. International organizations have attempted to standardize unit systems, symbols and the quantities to avoid confusion. As a result of international agreements, the "System International" or the SI system has emerged. The SI system consists of seven basic units, two supplementary units, and a series of derived units.

1.3.1 Base Units

The SI system is based on a choice of seven well-defined units, which by convention are regarded as dimensionally independent. The seven base units are as given in Table 1.1

Table 1.1: SI base units

Measurable attribute of phenomenon or matter	Name	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

1.3.2 Derived Units

Derived units are algebraic combinations of base units expressed by means of multiplication and division. Often, for simplicity, derived units carry special names and symbols that may be used to obtain other derived units. Some commonly used derived units are summarized in Table 1.2.

Table 1.2(a): Derived units expressed in terms of base units

Quantity	SI Units	
	Name	Symbol
Derived units expressed in terms of Base Units		
Area	square metre	m^2
Volume	cubic metre	m^3
Acceleration	metre per second squared	m/s^2
Density	kilogram per cubic metre	kg/m^3
Magnetic field strength	Ampere per metre	A/m
Concentration (of amount of substance)	mole per cubic metre	mol/m^3
Specific volume	cubic metre per kilogram	m^3/kg

Table 1.2(b): Derived units with specific names

Quantity	SI Units			
	Name	Symbol	Expression in terms of other units	Expression in terms of SI base units
Derived units with specific names				
Frequency	hertz	Hz		cycles.s^{-1}
Force	newton	N		m.kg.s^{-2}
Pressure	pascal	Pa	N/m^2	m^{-1}.kg.s^{-2}
Energy	joule	J	N/m	m^2.kg.s^{-2}
Power	watt	W	J/s	m^2.kg.s^{-3}
Capacitance	farad	F	C/V	$m^{-2}.kg^{-1}.s^{-4}.A^2$
Conductance	siemens	S	A/V	$m^{-2}.kg^{-1}.s^{-3}.A^2$

Table 1.2(c): Derived units expressed by means of special names

Quantity	SI Units		
	Name	Symbol	Expression in terms of SI base units
Derived units expressed by means of special names			
Dynamic viscosity	pascal second	Pa.s	m^{-1}.kg.s^{-1}
Moment of force	newton metre	N.m	m^2.kg.s^{-2}
Surface tension	newton per metre	N/m	kg.s^{-2}
Heat capacity, entropy	joule per kelvin	J/K	$m^2.kg.s^{-2}.K^{-1}$
Specific heat capacity	joule per kilogram kelvin	J/(kg.K)	$m^2.s^{-2}.K^{-1}$
Specific energy	joule per kilogram	J/kg	$m^2.s^{-2}$
Thermal conductivity	watt per metre kelvin	W/(m.K)	$m.kg.s^{-3}.K^{-1}$

1.3.3 Supplementary Units

This class of units contains two purely geometric units, which may be regarded either as base or derived units. Both of them are given in Table 1.3.

Table 1.3: SI supplementary units

Quantity	SI Units	
	Name	Symbol
Plane angle	radian	rad
Solid angle	steridian	sr

1.4 SYSTEM AND PROPERTIES

1.4.1 System

A careful description of the system is vital in engineering analysis. A region prescribed in space or a finite quantity of matter is called a system and that is enclosed by an envelope, which is stated to be the boundary of the system. The boundary of a system can be real, such as walls of a tank, or it can be an imaginary surface that encloses the system. For example, in Figure 1.1, the boundary in system A is along the walls of a storage tank; thus it does not include the pipe and the valve. However, in system B, the boundary envelops the tank, valve and the pipe. The composition of the system is described by the components present inside the system boundary.

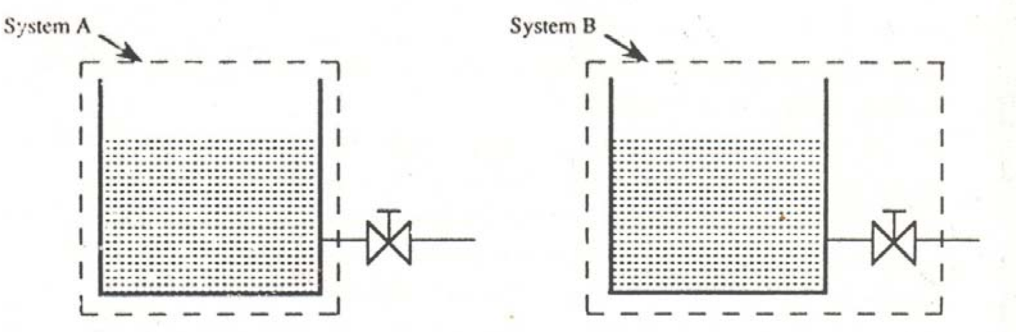

Figure 1.1: Examples of systems and their boundaries

Both closed and open systems are often encountered. In closed systems, the boundary of the system is impervious to any flow of matter. In an open system, heat and/or matter can flow into or out of the system. For example, a system boundary that contains only a small section of the wall is impervious to the flow of matter, and may be considered a close system. On the other hand, system B in Figure 1.1 is an open system since both heat and liquid can flow through the system.

1.4.2 Properties

Properties are those observable characteristics, such as pressure and temperature, which define the equilibrium state of a thermodynamic system. Properties do not depend on how the state of a system is attained: they are only functions of the state of a system. Thus, properties are independent of the process by which a system attained a certain state.

Intensive Properties

Intensive properties do not depend on the size of a system, such as temperature, pressure and density.

Extensive Properties

An extensive property depends on the size of the system: for example, mass, length, volume, energy. This definition implies that an extensive property of a system is a sum of respective partial property values of the components of a system. These properties, one of which may be mass are required to uniquely give an extensive property of a single component system.

The ratio of two extensive properties of a homogenous system is an intensive property. For example the ratio of two extensive properties mass and volume is density, which is an intensive property.

The state of a system is defined by independent properties. Once the properties become fixed, when the state of the system is defined, they are called dependent properties.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is a dimensionally consistent equation?

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2. Enlist different systems of measurement and state the most acceptable one among them.

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3. Write the SI units of the following:

Quantity	Unit	Quantity	Unit
Length		Frequency	
Thermodynamic temperature		Pressure	
Amount of substance		Power	
Area		Moment of force	
Density		Specific energy	
Concentration		Thermal conductivity	

4. Differentiate between the following

i) Open & closed systems

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ii) Intensive & extensive properties

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1.5 THERMAL PROCESSING

Since many of the processes utilized to preserve food products depend on the addition of thermal energy, it is important to understand the principles associated with food preservation through the addition of thermal energy. The design of a thermal process to achieve food preservation involves two principles: (a) the use of elevated temperatures to increase the rate of reduction in the microbial population present in the raw food material and (b) the transfer of thermal energy into the food product required to achieve the desired elevated temperatures.

The information in this section will address the typical parameters used to quantify the influence of elevated temperatures on reduction of microbial populations. Details will be presented in subsequent sections.

1.5.1 Influence of Elevated Temperatures on Microbial Populations

When microbial population in a food is exposed to an elevated temperature, changes in individual microbial cells within the population and a reduction in the viability of the microorganisms result in a reduction of the population with time of exposure when quantified by standard microbiological procedures. A typical pattern of microbial population change as a function of time when the population is exposed to an elevated temperature is illustrated in Figure 1.2. The reduction in population occurs in a logarithmic manner with increasing time at a given constant elevated temperature.

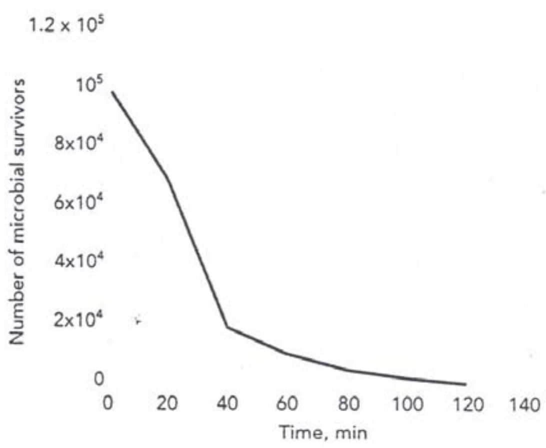

Figure 1.2: Changes in microbial population as a function of time at a constant elevated temperature

Decimal Reduction Time

The decimal reduction time (D Value) is defined as the time necessary for 90% reduction in the microbial population. When the microbial population is plotted against corresponding heating time on semi log coordinates, the D value is the time required for a one log cycle reduction in the number of microorganisms (Figure 1.3). The initial microbial population has no influence on the D value since the magnitude is directly related to the slope of the straight line. Exposure of the microbial population to higher temperatures results in a decrease in the D value. In fact, a plot of decimal reduction time as a function of temperature on semi log coordinates results in a linear relationship (Figure 1.4). This curve is known as thermal resistance curve.

Based on the definition, the following equation can be used:

$$\log N_0 - \log N = t/D \qquad (1.1)$$

or,

$$N/N_0 = 10^{-t/D} \qquad (1.2)$$

where N_0 is the initial number of microorganisms (t=o), N is the number of microorganisms surviving after heating for time 't' at a temperature and D is decimal reduction time for the microorganism under conditions of heating.

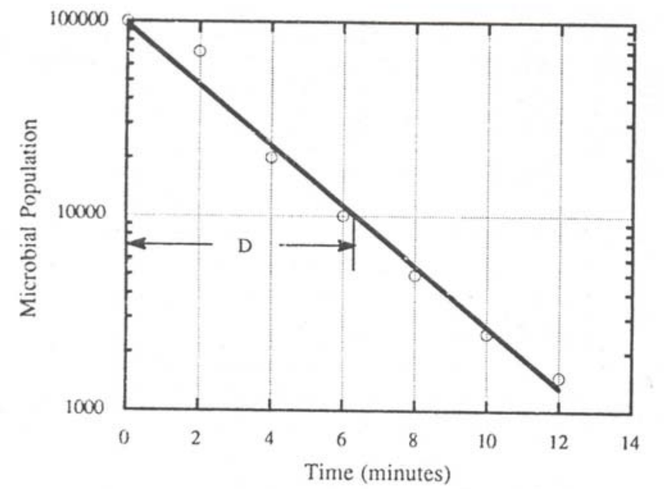

Figure 1.3: Semi-logarithmic plot of microbial population versus heating time at an elevated temperature

Thermal Resistance Constant

The temperature increase required to cause a one log cycle reduction in the decimal reduction time is defined as the thermal resistance constant (z). The thermal resistance constant, or z-value, is a second quantitative parameter normally used to quantify the thermal process required for a given microbial population. A large z-value suggests that a given increase in temperature of exposure for the microbial population results in a small change in decimal reduction time. In most situations, this observation would indicate that the microbial population contains vegetative cells or microbial spores; the spores exhibit greater heat resistance or higher z-value than vegetative populations which are characterized by a lower z-value. It is important to note that the complete characterization of the impact of elevated temperature on microbial population requires reference to both the decimal reduction time (D) and the thermal resistance constant (*z*). The *z*-value as shown in Figure 1.4 can be expressed by the following equation:

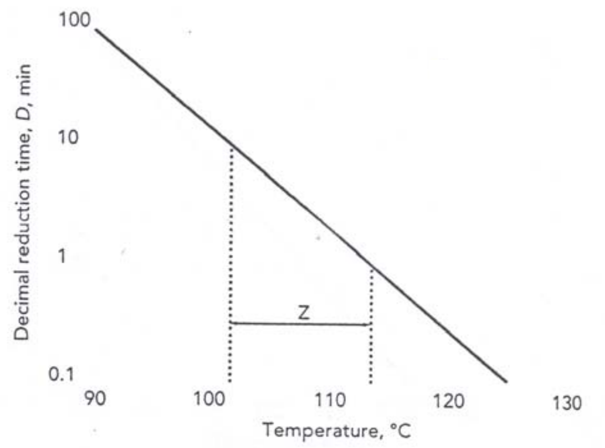

Figure 1.4: Thermal resistance curve of microbial population

$$z = \frac{T_2 - T_1}{\log D_{T_1} - \log D_{T_2}} \tag{1.3}$$

where D_{T_1} and D_{T_2} are decimal reduction times for micro-organisms at temperatures T_1 and T_2, respectively and 'z' is thermal resistant constant.

Thermal Death Time

The third quantitative parameter found frequently in thermal processing is the thermal death time, or F-value, which finds use in the actual thermal process. Thermal death time is defined as the time required for achieving a *stated reduction* in the microbial population at a given temperature. The key part of the definition is the stated reduction, which may be the reduction in the population of microbial pathogens required to establish product safety. Alternatively, the stated reduction may be the reduction in the population of a vegetative microorganism causing product spoilage, and the stated reduction is that required to achieve the desired product shelf-life.

A thermal death time curve would appear to be very similar to a thermal resistance curve (Figure 1.4), but would cover the entire range of times required to achieve the desired or stated reduction in microbial population. A typical thermal death time curve is presented in Figure 1.5. Note that the curve describes the entire reduction in microbial population from time zero until the population has been reduced to a defined level of microbial survivors. This point has been defined as the thermal death time, or F-value.

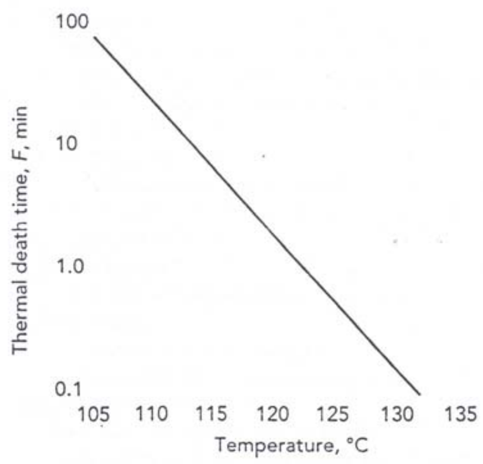

Figure 1.5: Thermal death time curve

The similarity in the thermal resistance and the thermal death time curve is evident from Figures 1.4 and 1.5. Each log cycle reduction in the microbial population on the thermal resistance curve represents a decimal reduction time, or D-value. It follows that F-values may be expressed as multiples of D-values. The most common of these relationships is F = 12D for *Clostridium botulinum* in *com*mercial sterilization of low acid foods. It must be emphasized that any given F-value will apply to a single elevated temperature. In other words, different elevated temperatures result in different F-values or times required achieving the same stated level of reduction in microbial population.

Inter-relationships

The relationships between microbial populations and time, as well as the impact of temperature, are very similar to the relationships used to describe kinetic parameters in first-order chemical reactions. The reaction rate constant *(k)* is used to describe the change in concentration of a reactant as a function of time. In microbial populations, the D-value is utilized to describe the same relationship. It follows that the relationship between the reaction rate constant *(k)* and the decimal reduction time (D) is given by Eq. (1.4):

$$k = \frac{2.303}{D} \tag{1.4}$$

The influence of temperature on reaction rate is described by Q_{10} or the activation energy constant (E). It follows that a relationship between Q_{10} and thermal resistance constant (z) must exist. It is relatively easy to demonstrate that this relationship is as shown in Eq. (1.5):

$$Q_{10} = 10^{\frac{10}{z}} \tag{1.5}$$

The relationship between the activation energy constant (E) and the thermal resistance constant (z) is more complex. It must be noted that the activation energy constant (E) is obtained from an Arrhenius plot: the natural logarithm of the reaction rate constant *(k)* versus the inverse of absolute temperature. Nevertheless, the relationship has been derived and presented in Singh and Heldman (1993) as Eq. (1.6):

$$E = \frac{2.303RT_A^2}{z} = \frac{19.15T_A^2}{z} \tag{1.6}$$

where R is the universal gas constant and T_A, represents the mid-point between two absolute temperatures used to define the z-value in the relationship. The relationship between the activation energy constant and the thermal resistance constant applies over limited ranges of temperature where the experimental data utilized to quantify the z-value were measured.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define thermal death time & decimal reduction time.

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2. Compute the first order rate constant corresponding to the decimal reduction time of 4.1 minutes.

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3. Estimate Q_{10} for a z value of 11°C.

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4. Estimate the activation energy of a microorganism having a thermal resistance constant of 11°C at 100°C?

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1.6 REFRIGERATION

Refrigeration system allows transfer of heat from the cooling chamber to a location where the heat can be discarded. The transfer of heat is accomplished by using a refrigerant, which like water changes state – from liquid to vapour. The primary purpose of refrigerating foods is to extend shelf-life by slowing down degradatory reactions and limiting microbial growth. Through reduction in rates of chemical, biochemical and microbial kinetics (rates of lipid oxidation, non enzymatic browning, sugar conversion, enzymatic browning, and respiration reactions), low temperature storage can extend the shelf-life of fresh and processed foods. Typically, refrigerated storage means holding food in a temperature range of –1 to 8°C.

Other factors besides low temperature may influence shelf-life of refrigerated foods. For fresh foods, these include the type of food and variety, the condition of the food at harvest (mechanical damage, microbial contamination, and degree of maturity), and the relative humidity of storage atmosphere. For processed foods, factors affecting shelf life include type of food, degree of microbial or enzyme destruction during processing, hygienic factors during processing and packaging, and the nature of the package (barrier properties).

1.6.1 Components of a Refrigeration System

The major components of a simple mechanical vapour compression refrigeration system are shown in Figure 1.6. As the refrigerant flows through these components its phase changes from liquid to gas and then back to liquid. At location D, just prior to the entrance of the expansion valve, the refrigerant is in a saturated liquid state. After passing through the expansion valve, the refrigerant experiences a drop in pressure accompanied by a drop in temperature. Due to the drop in pressure, some of the liquid refrigerant changes to gas. The liquid gas leaving the expansion valve is termed 'flash gas'.

The liquid/gas mixture enters the evaporator coils at location E. In the evaporator, the refrigerant completely vaporizes to gas by accepting heat from the media surrounding the evaporator coils. The saturated vapour may also get superheated due to gain of additional heat from the surroundings.

The saturated or superheated vapours enter the compressor, where the refrigerant is compressed to a high pressure. This high pressure must be below the critical pressure of the refrigerant and high enough to allow condensation of the refrigerant at a temperature slightly higher than that of commonly available heat sinks, such as ambient air or water. Inside the compressor, the compression process of the vapours occurs at constant entropy (called an isentropic process). As the pressure of the refrigerant increases, the temperature increases, and the refrigerant become superheated.

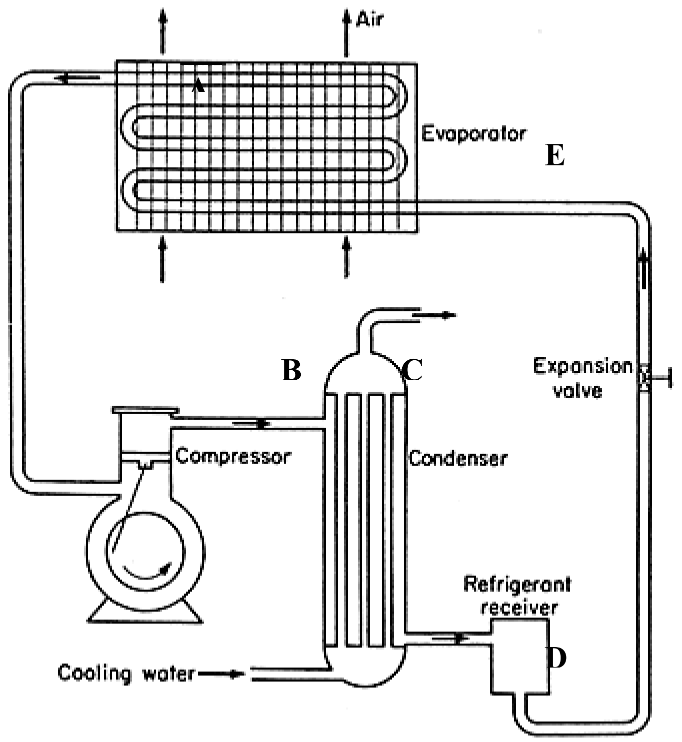

Figure 1.6: Mechanical refrigeration circuit

The superheated vapours are then conveyed to the condenser. Using either an air cooled or water cooled condenser, the refrigerant discharges heat to the surrounding media. The refrigerant condenses back to the liquid state in the condenser (saturated liquid). The temperature of the refrigerant may decrease below that of its condensation temperature (sub cooled) due to additional heat discharged to the surrounding media. The saturated or sub cooled liquid then enters the expansion valve and the cycle continues.

The process can also be followed on the pressure-enthalpy chart shown in Figure 1.7.

1.6.2 Some Useful Mathematical Expressions

Cooling Load

The cooling load is the rate of heat energy removal from a given space (or object) in order to lower the temperature of that space (or object) to a desired level. A typical unit of cooling load used in commercial practice is 'ton of refrigeration'. One ton of refrigeration is equivalent to the amount of heat required to melt one ton of ice in one day at 0^0 C {(1000 kg x 336 kJ/kg)/24 hr} = (336000 kJ / 86400 s) = 3.888 kW. Thus a mechanical refrigeration system that has a capacity to absorb heat from the refrigerated space at the rate of 3.888 kW is rated as one ton of refrigeration.

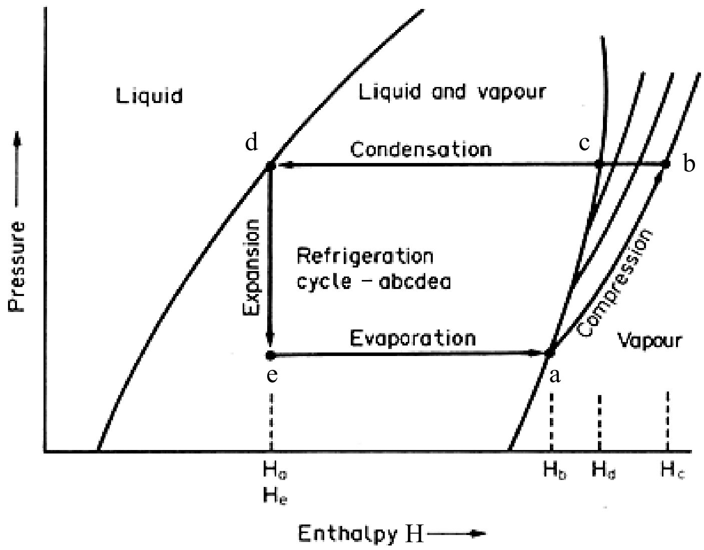

Figure 1.7: Pressure/enthalpy chart

The factors which contribute to the cooling load include the sensible heat, heat of respiration (in case of fresh produce); heat infiltration through walls, floor and ceiling; heat gain through doors; heat given by lights, people and use of fork lifts for material handling; etc.

Coefficient of Performance

The coefficient of performance (C.O.P.) is defined as a ratio between the heat absorbed by the refrigerant as it flows through the evaporator to the heat equivalence of the energy supplied to the compressor. In other words, it is the ratio of the useful refrigeration effect obtained from the system to the work expended on it to produce that effect.

$$C.O.P. = \frac{H_a - H_e}{H_b - H_a} \tag{1.7}$$

where H_a is heat content of vapour learning evaporator, H_b is heat content of vapour learning compressor, H_d or H_e is heat content of liquid entering evaporator.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe the principle behind shelf-life extension through refrigeration.

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2. Enlist the various components of a vapour compression refrigeration system along with their functions.

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3. Define cooling load and C.O.P.

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1.7 FOOD FREEZING

Food freezing is a preservation process that depends on the reduction of product temperatures to levels well below the temperature at which ice crystals begin to form within the food. By reducing the temperature of the product to –10°C to –20°C, the normal reactions that cause deterioration of foods are reduced to negligible or minimal rates. These temperature levels eliminate microbial growth as a concern in shelf-life of the food product. As would be expected, the shelf-life of a frozen food is a function of temperature, with lower temperatures leading to longer shelf-life.

The limitations of freezing as a food preservation process include both quality concerns and energy requirements. The formation of ice crystals within the structure of most food products creates changes in the structure that are at times irreversible and most often cause negative changes in the quality characteristics of the product. The refrigeration requirements associated with the food-freezing process, as well as maintaining the low temperatures associated with frozen food storage and distribution are factors that must be considered while evaluating the costs of this preservation process. The value of the shelf-life extension achieved by food freezing must be balanced against the added costs associated with energy requirements for the production and storage of the frozen foods.

1.7.1 Theory

In theory, the freezing process is the removal of the thermal energy from the food product to the extent required to reduce the temperature below the freezing temperature of water. The thermal energy removed, as a part of freezing is primarily latent heat of fusion required to convert water to ice within the product.

If the temperature is monitored at the thermal center of food (the point that cools most slowly) as heat is removed, a characteristic curve is obtained (Figure 1.8).

The six portion of the curve are as follows:

AS The food is cooled to below its freezing point θ_f which, with the exception of pure water, is always below 0°C. At point S the water remains liquid although the temperature is below the freezing point. This phenomenon is known as sub-cooling and may be as much as 10°C below the freezing point

SB The temperature rises rapidly to the freezing point as ice crystals begin to form and latent heat of crystallization is released.

BC Heat is removed from the food at the same rate as before. Latent heat is removed and ice forms, but the temperature remains almost constant. The freezing point is depressed by the increase in solute concentration in the unfrozen liquor, and the temperature therefore falls slightly. It is during this stage that the major part of the ice is formed.

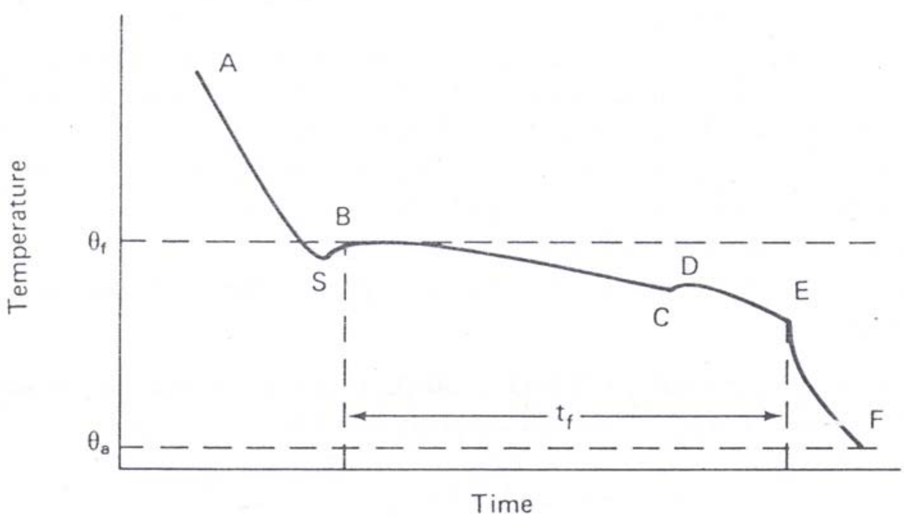


Figure 1.8: Time temperature relationships during freezing

CD One of the solutes becomes supersaturated and crystallizes out. The latent heat of crystallization is released and the temperature rises to the eutectic temperature for that solute

DE Crystallization of water and solutes continues. The total time t_f taken (the freezing plateau) is determined by the rate at which heat is removed.

EF The temperature of the ice-water mixture falls to the temperature of the freezer. A proportion of the water remains unfrozen at the temperature used in commercial freezing; the amount depends on the type and composition of the food and the temperature of freezing.

Ice Crystal Formation

The freezing point of a food is the temperature at which a minute crystal of ice exists in equilibrium with the surrounding water. However, before an ice crystal can form, a nucleus of water molecules must be present. Nucleation therefore precedes ice crystal formation. The rate of ice crystal growth during freezing is controlled by the rate of heat transfer for the majority of the freezing plateau. The rate of mass transfer does not control the rate of crystal growth except towards the end of the freezing period when solutes become more concentrated. The time taken for the temperature of the food to pass through the critical zone (Figure 1.9) therefore, determines the number and the size of the ice crystals.

Solute Concentration

The increase in solute concentration during freezing causes changes in pH, viscosity and redox potential of the unfrozen liquor. As the temperature falls individual solutes reach saturation point and crystallizes out. The temperature at which a crystal of an individual solute exists in equilibrium with the unfrozen liquor and ice is its eutectic temperature. However, it is difficult to identify individual eutectic temperatures in the complex mixture of solutes in foods, and the term final eutectic temperature is used. This is the lowest temperature of the solutes in the food. Maximum ice crystal formation is not possible until this temperature is reached. Commercial foods are not frozen to such low temperatures and unfrozen water is therefore always present.

Volume Changes

The volume of ice at 0^0 C is 9% greater than that of pure water, and an expansion of foods after freezing would therefore be expected. However, the degree of expansion varies considerably owing to the moisture content (higher moisture content produce greater changes in volume), cell arrangement, the concentration of solutes (high concentrations reduce the freezing point) and the freezer temperature (this determines the amount of unfrozen water and hence the degree of expansion). Temperatures below 0^0 C cause shrinkage in the volume of ice formed during freezing process.

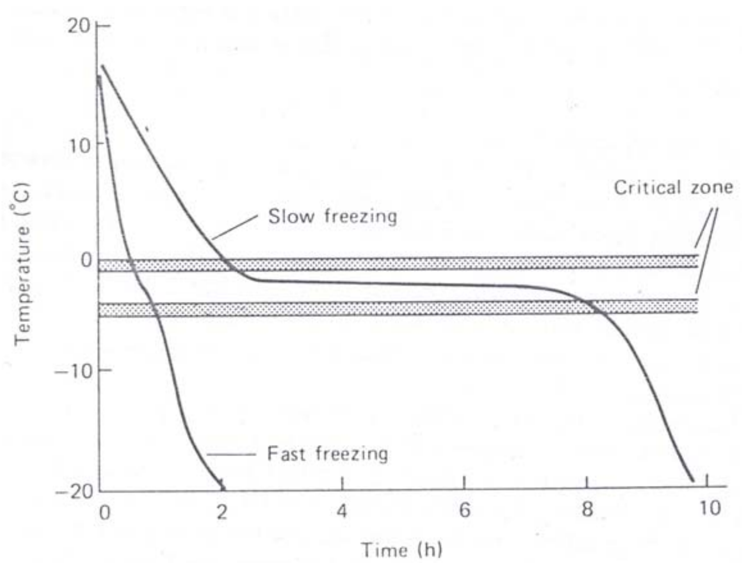


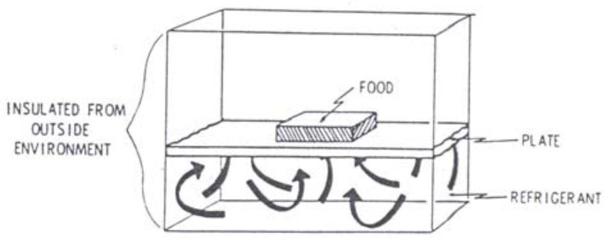
Figure 1.9: Temperature changes of food through the critical zone during freezing

1.7.2 Freezing Systems

The freezing process can be accomplished using either indirect or direct contact systems. Most often, the type of system used will depend on the product characteristics, before and after freezing is completed.

Indirect Contact Systems

In numerous food products freezing systems the product and the refrigerant are separated by a barrier throughout the freezing process. This is called an indirect contact system (Figure 1.10). Although many systems use a non-permeable barrier between product and refrigerant, indirect freezing systems include any system without direct contact, including those where the package material becomes the barrier. These include plate freezer, air blast freezer and freezer for liquid foods.



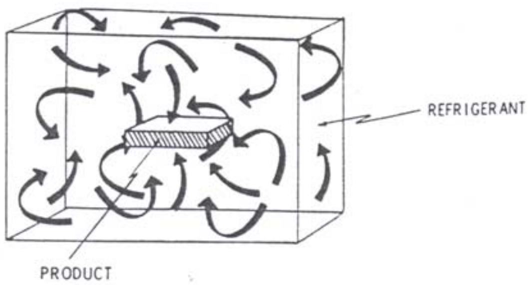


Figure 1.10: Schematic diagram of indirect contact freezing

Figure 1.11: Schematic diagram of direct contact freezing

Direct Contact Systems

Direct contact freezing systems operate with direct contact between the refrigerant and the product (Figure 1.11). In most situations these systems operate more efficiently since there is no barrier to heat transfer between the refrigerant and the product. All direct contact freezing systems are designed to achieve rapid freezing, and the term individual quick freezing (IQF) applies. This includes fluidized bed freezing immersion freezing and cryogenic freezing.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define food freezing.

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2. Define eutectic point.

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3. Enlist the factors affecting volume changes during freezing.

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4. Differentiate between indirect and direct contact freezing systems.

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1.8 EVAPORATION

Evaporation is an important unit operation commonly employed to remove water from dilute liquid foods to obtain concentrated liquid products (for e.g. manufacture of tomato puree from juice). Removal of water from foods provides microbiological stability and assists in reducing packaging, transportation and storage costs. Evaporation is also a necessary step before drying and crystallization process. Evaporation differs from dehydration, since the final product of evaporation process remains in liquid state.

The evaporator in which the vapour produced are discarded without further utilizing its inherent heat is called a single effect evaporator, whereas the evaporator in which the inherent heat of the vapour is reused again as heating medium is called a multiple effect evaporator.

The evaporation process is largely dependent on the principle of heat transfer and the factors, which hamper heat transfer, are the major impediments for the process. Some of these factors are: (1) Boiling point rise, (2) Heat sensitivity of the liquid, (3) Fouling & foaming properties of the food, etc.

1.8.1 Boiling Point Elevation

Boiling point elevation of a solution (liquid food) is defined as the increase in boiling point over that of pure water, at a given pressure. A simple method to estimate boiling point elevation is the use of Duhring's rule. The Duhring's rule states that a linear relationship exists between the boiling point temperature of a solution and the boiling point temperature of water at the same pressure. Duhring lines for sodium chloride – water system are shown in Figure 1.12.

1.8.2 Types of Evaporators

Several types of evaporators are used in the food industry. In the following paragraphs we would discuss some of the most commonly used evaporators.

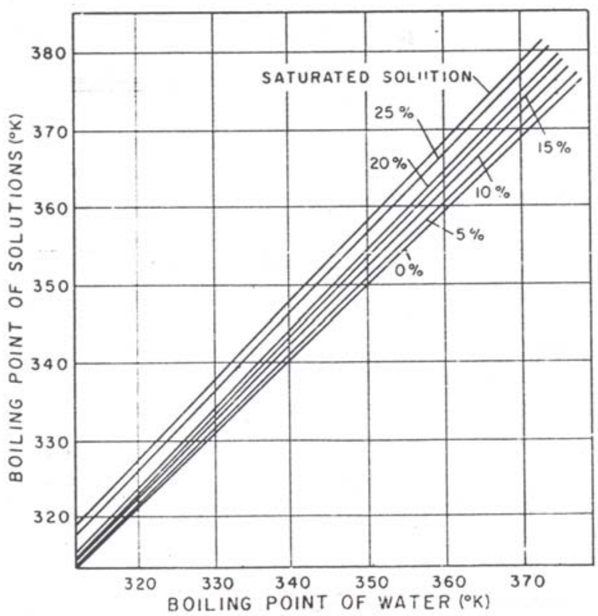


Figure 1.12: Duhring lines for sodium chloride – water system

Batch Type Pan Evaporator

One of the simplest and perhaps oldest types of evaporators used in food industry is the batch-type pan evaporator (Figure 1.13). The product is heated in a steam jacketed spherical vessel. The heating vessel is either open to atmosphere or connected to a condenser and vacuum system.

Heating of the product occurs mainly due to natural convection, resulting in smaller convective heat transfer coefficients. The poor heat transfer coefficients substantially increase the residence time of the product and reduce the processing capacities of these evaporators.

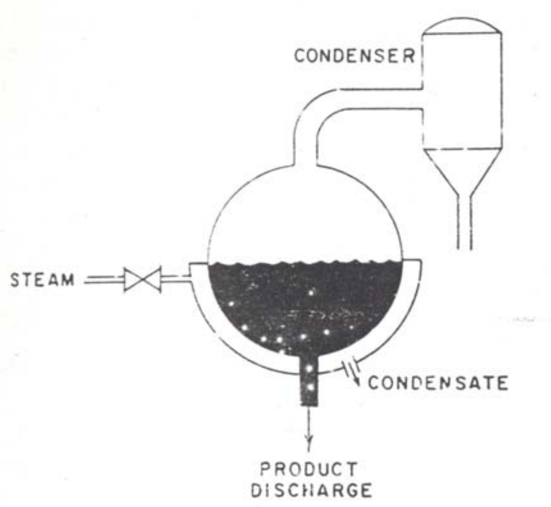


Figure 1.13: Batch type pan evaporator

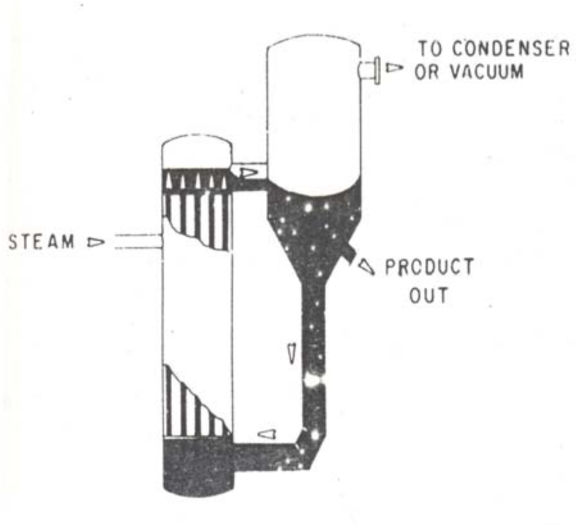


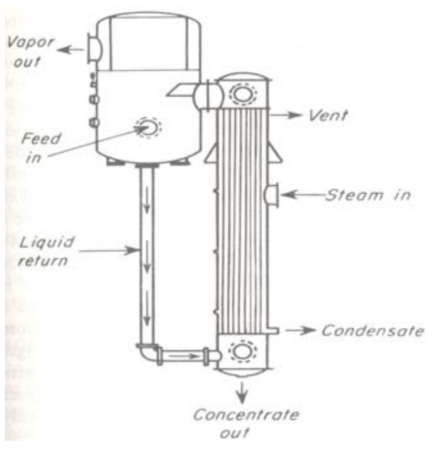
Figure 1.14: Natural circulation evaporator

Natural Circulation Evaporators

In natural circulation evaporators (Figure 1.14), short vertical tubes are arranged inside a steam chest. The whole calendria (tubes and steam chest) is located at the bottom of the vessel. The product when heated rises through these tubes by natural circulation while steam condenses outside the tubes. Evaporation takes place inside the tubes and the product is concentrated. The concentrated liquid falls back to the base of the vessel through a central annular section.

Rising Film Evaporator

In a rising film evaporator (Figure 1.15), a low viscosity liquid food is allowed to boil inside 10-15 m long vertical tubes. The tubes are heated from outside with steam. The liquid rises inside these tubes by vapours formed near the bottom of the heating tubes. The upward movement of vapour causes a thin liquid film to move rapidly upward. A temperature differential of at least 14°C between the product and the heating medium is necessary to obtain a well-developed film. High convective heat-transfer coefficients achieved in these evaporators mostly makes the operation once through. However, liquid can be recirculated to obtain the required solid concentration.



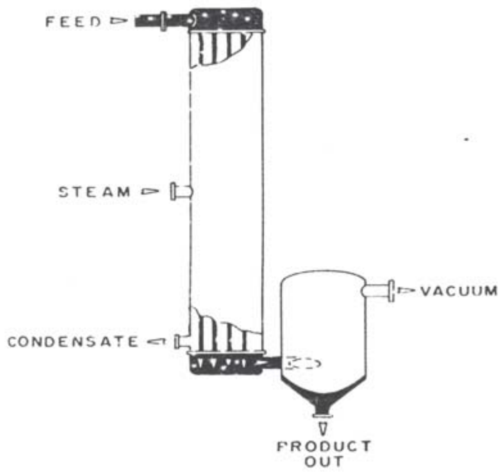


Figure 1.15: Rising film evaporator

Fig 1.16: Falling film evaporator

Falling Film Evaporator

In contrast to the rising film evaporator, the falling film evaporator has a thin liquid film moving downward under gravity on the inside of the vertical tubes (Figure 1.16). The distribution of liquid in a uniform film flowing downward is accomplished by the use of specially designed distributors or spray nozzles. The falling film evaporator can handle more viscous liquids than the rising film type. These evaporators are best suited for highly heat sensitive products. Typical residence time in a falling film evaporator is 20-30 seconds, compared with residence time of 3-4 minutes in a rising film evaporator.

Rising / Falling Film Evaporator

In the rising / falling film evaporator, the product is concentrated by circulation through a rising film section followed by a falling film section of the evaporator. As shown in Figure 1.17, the product is first partially concentrated as it ascends through a rising tube section, followed by the pre-concentrated product descending through a falling film section; there it attains its final concentration.

Forced Circulation Evaporators

The forced circulation evaporator involves a non contact heat exchanger where liquid food is circulated at high rates (Figure 1.18). A hydrostatic head, above the top of the tubes, eliminates any boiling of the liquid. Inside the separator, absolute pressure is kept slightly lower than that in the tube bundle. Thus, the liquid entering the separator flashes to form a vapour. The temperature difference across the heating surface in the heat exchanger is usually 3-5°C. Axial flow pumps are generally used to maintain high circulation rates with linear velocities of 2-6 m/s, compared with a linear velocity of 0.3 – 1 m/s in natural convection evaporators. Both capital and operating costs of these evaporators are very low in comparison to other types of evaporators.

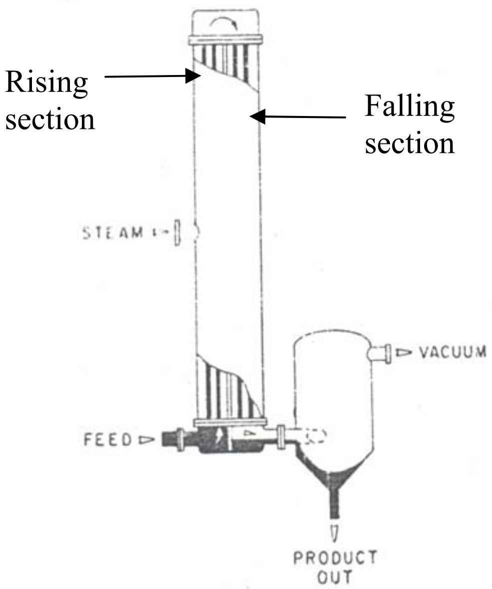


Figure 1.17: Rising / Falling film evaporator

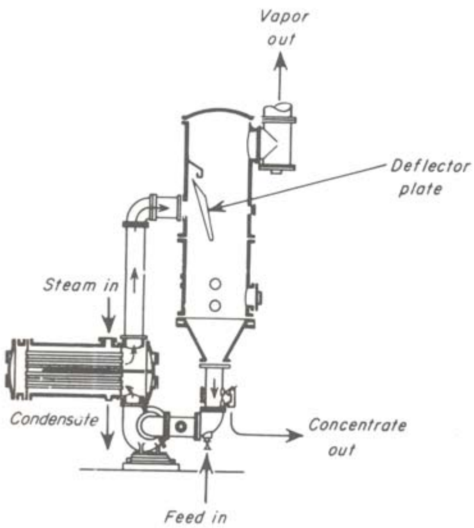


Figure 1.18: Forced circulation evaporator

Agitated Thin Film Evaporator

For very viscous fluid foods, feed is spread on the inside of the cylindrical heating surface by wiper blades, as shown in Figure 1.19. Due to high agitation, considerably higher heat transfer rates are obtained. The cylindrical configuration results in low heat transfer area per unit volume of the product. High pressure steam may be used as the heating medium to obtain high wall temperatures for reasonable evaporation rates. The major disadvantages are the high capital and maintenance costs and low processing capacity.

In addition to the tubular shape, plate evaporators are also used in the industry. Plate evaporators use the principles of rising / falling film, falling film, wiped film and forced circulation evaporators.

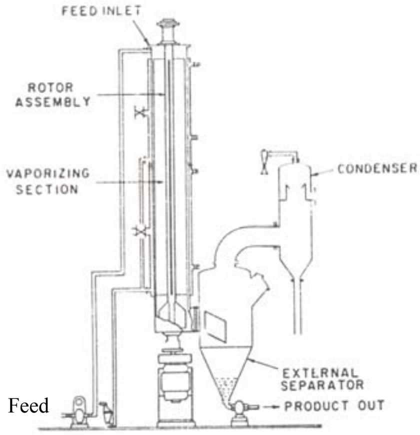


Figure 1.19: Agitated thin film evaporator

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between evaporation and dehydration.

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2. Define boiling point elevation.

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3. Write short notes on the following.

    a) Batch type pan evaporator
    b) Rising film evaporator
    c) Forced circulation evaporator
    d) Agitated thin film evaporator

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1.9 DEHYDRATION

Drying is one of the oldest methods of preserving food. Primitive societies practiced the drying of meat and fish in the sun long before recorded history. Today the drying of foods is still important as a method of preservation. Dried foods can be stored for long periods without any deterioration in quality. The principal reasons for this are that the microorganisms, which cause food spoilage and decay, are unable to grow and multiply in the absence of sufficient water and many of the enzymes which promote undesired changes in the food cannot function without water.

Preservation is the principal reason for drying, but drying can also occur in conjunction with other processing. For example, in the baking of bread, application of heat expands gases, changes the structure of the protein and starch molecules and dries the loaf.

Drying of foods implies the removal of water from the foodstuff. In most cases, drying is accomplished by vaporizing the water that is contained in the food, and to do this the latent heat of vaporization must be supplied. There are, thus, two important process-controlling factors that enter into the unit operation of drying:

a) Transfer of heat to provide the necessary latent heat of vaporization,

b) Movement of water or water vapour through the food material and then away from it to effect separation of water from foodstuff.

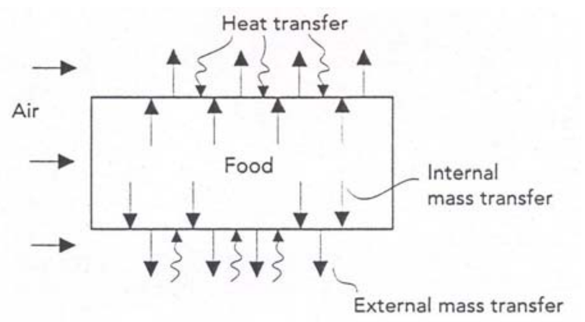

Figure 1.20: Principle of drying of food

1.9.1 Basic Drying Theory

Pure water can exist in three states, solid, liquid and vapour. The state in which it is at any time depends on the temperature and pressure conditions and it is possible to illustrate this on a phase diagram, as in Figure 1.21.

If we choose any condition of temperature and pressure and find the corresponding point on the diagram, this point will lie, in general, in one of the three-labelled regions, solid, liquid, or gas. This will give the state of the water under the chosen conditions.

Under certain conditions, two states may exist side by side, and such conditions are found only along the lines of the diagram. Under one condition, all three states may exist together; this condition arises at what is called the triple point, indicated by point O on the diagram. For water it occurs at 0.0098°C and 0.64 kPa (4.8 mm of mercury) pressure.

If heat is applied to water in any state at constant pressure, the temperature rises and the condition moves horizontally across the diagram, and as it crosses the boundaries a change of state will occur. For example, starting from condition A on the diagram adding heat warms the ice, then melts it, then warms the water and finally evaporates the water to condition A'. Starting from condition B, situated below the triple point, when heat is added, the ice warms and then sublimes without passing through any liquid state.

Liquid and vapour coexist in equilibrium only under the conditions along the line OP. This line is called the vapour-pressure line. The vapour pressure is the measure of the tendency of molecules to escape as a gas from the liquid.

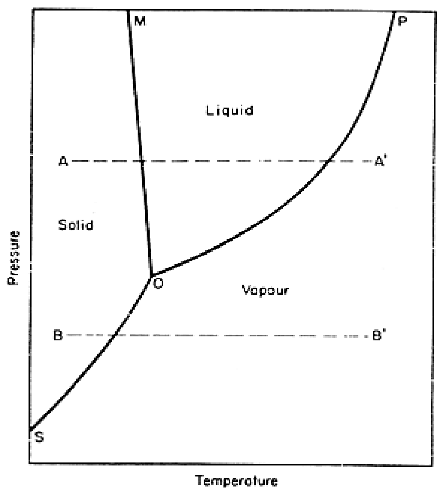

Figure 1.21: Phase diagram for water

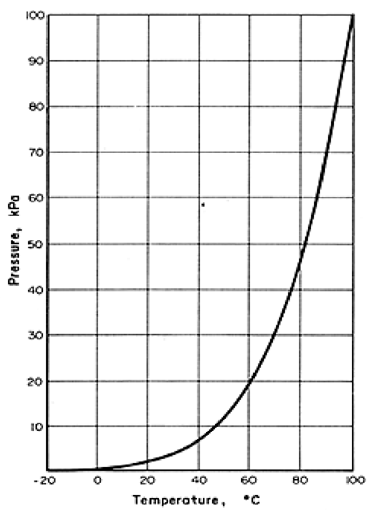

Fig 1.22: Vapour pressure/temperature curve for water

Boiling occurs when the vapour pressure of the water is equal to the total pressure on the water surface. The boiling point at atmospheric pressure is of course 100°C. At pressures above or below atmospheric, water boils at the corresponding temperatures above or below 100°C as shown in Figure 1.22 for temperatures below 100°C.

Recently, state diagrams have been employed to depict conditions of water in foods and its use has improved our knowledge of drying technology. The state diagram shown in figure 1.23 for simple system of solute and solvent, is a phase diagram based on components of the food product supplemented by the glass transition curve. The glass transition curve represents a meta stable transition where viscosity is effectively so high that the product does not 'flow' over time scale of importance to food stability. Below this curve on the state diagram, the food is stable to diffusion related processes (such as moisture migration) for extremely longer times.

Heat Transfer in Drying

The rates of drying are generally determined by the rates at which heat energy can be transferred to the water or to the ice in order to provide the latent heats, though under some circumstances the rate of mass transfer (removal of the water) can be limiting. All three of the mechanisms by which heat is transferred - conduction, radiation and convection - may enter into drying. The relative importance of the mechanisms varies from one drying process to another and very often one mode of heat transfer predominates to such an extent that it governs the overall process.

As an example, in air drying the rate of heat transfer is given by:

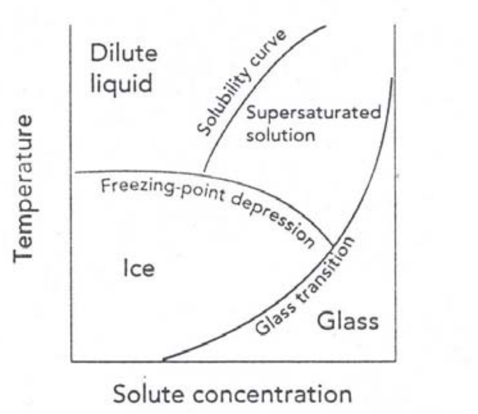

Figure 1.23: State diagram for a simple binary mixture

$$q = UA\,(T_a - T_s) \tag{1.8}$$

where q is the heat transfer rate in J s^{-1}, U is the overall heat-transfer coefficient in J s^{-1} m^{-2} k^{-1}, A is the area through which heat flow is taking place, T_a is the air temperature and T_s is the temperature of the surface which is getting dried.

In cases where substantial quantities of heat are transferred by radiation, it should be remembered that the surface temperature of the food might be higher than the air temperature. Estimates of surface temperature can be made using the relationships developed for radiant heat transfer although the actual effect of combined radiation and evaporative cooling is complex. Convection coefficients also can be estimated using the standard equations.

As drying proceeds, the character of the heat transfer situation changes. Dry material begins to occupy the surface layers and conduction must take place through these dry surface layers that are poor heat conductors. Therefore, the heat is transferred to the drying region progressively more slowly.

Mass Transfer in Drying

In heat transfer, heat energy is transferred under the driving force provided by a temperature difference, and the rate of heat transfer is proportional to the potential (temperature) difference and to the properties of the transfer system characterized by the heat-transfer coefficient. In the same way, mass is transferred under the potential gradient force provided by a partial pressure or concentration difference. The rate of mass transfer is proportional to the potential (pressure or concentration) gradient and to the properties of the transfer system characterized by a mass-transfer coefficient.

Writing the relationship symbolically, analogous to heat transfer (Eq. 1.8), we have

$$w = k_G A(H_a - H_s) \tag{1.9}$$

where w is the mass being transferred kg s^{-1}, A is the area through which the transfer is taking place, k_G is the mass-transfer coefficient in this case in units kg m^{-2} s^{-1}, and the quantity within brackets i.e., $(H_a - H_s)$ is the humidity difference in kg kg^{-1}(kg of moisture per kg of air).

Unfortunately the application of mass-transfer equation is not as straightforward as heat transfer, one reason being because the movement pattern of moisture changes as drying proceeds. Initially, the mass (moisture) is transferred from the surface of the material and later, to an increasing extent, from deeper within the food to the surface and thence to the air. So the first stage is to determine the relationships between the moist surface and the ambient air and then to consider the diffusion through the food. In studying the surface/air relationships, it is necessary to consider mass and heat transfer simultaneously. Air for drying is usually heated and it is also a major heat-transfer medium. Therefore, it is necessary to look carefully into the relationships between air and the moisture it contains.

Factors Influencing Drying

There are many factors that influence the rate of drying. These are related to either: (1) the process conditions present during drying, as determined by dryer type and operating conditions, or (2) the nature of the food product placed inside the dryer. The process conditions include dry look temperature, air velocity, wet bulb depression, pressure etc. whereas those of food product include surface area, constituent orientation, cellular structure, type and concentration of solutes.

Drying Methods

The methods involved in industrial drying of foods include: (1) Cabinet drying, (2) Tunnel drying, (3) Spray drying, (4) Vacuum drying, (5) Foam mat drying, (6) Freeze drying, (7) Fluidized bed drying, (8) Microwave drying, (9) Drum drying etc. The principles of different drying methods and the equipments used will be dealt in detail in subsequent blocks.

Check Your Progress Exercise 6

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Enumerate the principle of drying and its controlling factors?

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2. Define triple point of water.

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3. Triple point of pure water occurs at ________°C temperature and __________ kPa pressure.

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4. Define vapour-pressure line.

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5. Define glass transition curve.

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6. What is the driving force for heat and mass transfer during drying of foods?

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7. Enlist the factors that influence drying.

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1.10 LET US SUM UP

We have learnt that there are magnitudes of various quantities and properties, which do not make sense unless, qualified with appropriate units. Although there are different systems of units such as MKS, CGS, FPS and SI, it is the SI system of units that is internationally accepted. A system for the purpose of analysis may be either a closed or an open system. Thermal processing of food is required to ensure that the population of harmful micro-organisms is reduced to acceptable level and then not allowed to grow for an intended period of time. The concepts of Decimal reduction time, thermal resistance constant and thermal death time have been presented. Then, the processes of evaporation, refrigeration and dehydration as they relate to food processing have been introduced. Simple relationships for estimating the extents of these unit operations have been presented.

1.11 KEY WORDS

Dimensions : A dimension defines a physical entity, which can be observed and / or measured, quantitatively.

Units : A unit expresses the quantitative value of a dimension.

Open system : The composition of the system is described by the components present inside and outside the system boundary.

Close system : The composition of the system is described by the components present inside the system boundary.

Intensive Properties : Properties that does not depend on the size of a system.

Extensive Property : Depends on the size of the system: for example, mass, length, volume, energy. This definition implies that an extensive property of a system is a sum of respective partial property values of the components of a system.

Decimal reduction time : The decimal reduction time (D) is defined as the time necessary for 90% reduction in the microbial populationly heating at a constant temperature.

Thermal resistance constant : It is defined as the temperature increase required to cause a one log cycle reduction in the decimal reduction time.

Thermal death time : Thermal death time is defined as the time required for achieving a *stated reduction* in the microbial population at a given temperature.

Evaporator : Completely vaporizes the refrigerant by heating it.

Compressor : Compresses the refrigerant at constant entropy.

Condenser : Condenses the refrigerant after going the heat to the surrounding medium

Expansion valve : It is the point of differentiation between the high pressure and low pressure sides of the refrigeration cycle.

Cooling load : The cooling load is the rate of heat energy removal from a given space (or object) in order to lower the temperature of that space (or object) to a desired level.

Coefficient of performance : The coefficient of performance (C.O.P.) is defined as a ratio between the heat absorbed by the refrigerant as it flows through the evaporator to the heat equivalence of the energy supplied to the compressor.

Eutectic temperature : The temperature at which a crystal of an individual solute exists in equilibrium with the unfrozen liquor and ice is its eutectic temperature.

Boiling point elevation : Boiling point elevation of a solution (liquid food) is defined as the increase in boiling point over that of pure water, at a given pressure.

Triple point : Triple point of water is defined as a condition in which pure water can exist in all the three states i.e., solid, liquid and vapour.

1.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. A dimensionally consistent equation is the one, which is balanced on both of its sides in terms of the dimensions, i.e. the LHS & RHS are dimensionally equal.
2. The different measuring systems are FPS, CGS, MKS and SI. The most acceptable and standard among them is the SI system.
3.

Quantity	Unit	Quantity	Unit
Length	m	Frequency	s^{-1}
Thermodynamic temperature	K	Pressure	$m^{-1}.kg.s^{-2}$
Amount of substance	Mol	Power	$m^2.kg.s^{-3}$
Area	m^2	Moment of Force	$m^2.kg.s^{-2}$
Density	Kg m^{-3}	Specific Energy	$m^2.s^{-2}$
Concentration	Mol m^{-3}	Thermal conductivity	$m.kg.s^{-3}.K^{-1}$

4. i) Open system is one which allows flow of heat and/or matter into or out of the system along its boundary whereas closed system is one in which the boundary is impervious to any flow of matter.

   ii) Intensive properties are those, which do not depend on the size of the system whereas extensive properties are those, which are dependent on the size of the system.

Check Your Progress Exercise 2

1. Thermal death time is defined as the time required to achieve a *stated reduction* in the microbial population at a given temperature, whereas, the decimal reduction time D is defined as the time necessary for 90% reduction in the microbial population.

2. $$k = \frac{2.303}{D} = \frac{2.303}{4.1} = 0.56/\min..$$

3. $$Q_{10} = 10^{10/z} = 10^{10/11} = 8.1$$

4. $$E_A = \frac{19.15}{z} T_A^2 = \frac{19.15}{11}(383)^2 = 2.55X10^5\, kJ/kg$$

Check Your Progress Exercise 3

1. Refrigeration involves the principle of transfer of heat from the cooling chamber or object to a location where the heat can be discarded with the use of a refrigerant, which like water changes state – from liquid to vapour.

2. a) Evaporator: It completely vaporizes the refrigerant by accepting heat from the media surrounding the coils.

   b) Compressor: It compresses the refrigerant to a high pressure so as to condense it at a temperature slightly higher than the heat sink.

   c) Condenser: Condenses the refrigerant to saturated / sub-cooled liquid by discharging heat to the surrounding media.

   d) Expansion valve: It is essentially a metering device that controls the flow of refrigerant into the evaporator. It separates the high pressure region from the low pressure region.

3. Cooling load is defined as the rate of heat energy removal from a given space (or object) in order to lower the temperature of that space (or object) to a desired level whereas C.O.P. is defined as the heat absorbed by the refrigerant as it flows through the evaporator to the heat equivalence of the energy supplied to the compressor.

Check Your Progress Exercise 4

1. Food freezing is defined as a preservation process that depends on the reduction of product temperatures to levels well below the temperature at which ice crystals begin to form within the food.

2. Eutectic temperature is defined as the temperature at which a crystal of an individual solute exists in equilibrium with the unfrozen liquor and ice.

3. The factors affecting volume changes during freezing are: (1) moisture content, (2) cell arrangement, (3) concentration of solutes and (4) freezer temperature.

4. In indirect contact freezing systems the product and the refrigerant are separated by a barrier throughout the freezing process whereas in direct contact freezing systems there is no such barrier between the refrigerant and the product.

Check Your Progress Exercise 5

1. Evaporation is a unit operation commonly used to remove water from dilute liquid foods to obtain concentrated liquid products whereas dehydration is used to remove water and obtain dry solid product i.e evaporation involves partial removal of water from the food products whereas drying involves complete removal of moisture from the foods.

2. Boiling point elevation of a solution (liquid food) is defined as the increase in boiling point over that of pure water, at a given pressure.

Check Your Progress Exercise 6

1. Drying of foods implies the removal of water from the foodstuff, which is accomplished by supplying the latent heat of vaporization.

   The two important process-controlling factors that enter into the unit operation of drying are:

   a) Transfer of heat to provide the necessary latent heat of vaporization,

   b) Movement of water/water vapour through the food material and then away from it to effect separation of water from foodstuff.

2. Triple point of water is defined as a condition in which pure water can exist in all the three states i.e., solid, liquid and vapour.

3. 0.0098°C and 0.64 kPa.

4. Vapour-pressure line is defined as a line along which liquid and vapour coexist in equilibrium.

5. The glass transition curve represents a metastable transition where viscosity is effectively so high that the product does not ‘flow’ over time scale of importance to food stability.

6. The driving force for heat transfer is temperature gradient whereas that of mass transfer is pressure or concentration.

7. The factors that influence the rate of drying are (1) the process conditions present during drying, as determined by dryer type and operating conditions (temperature, air velocity, relative humidity, pressure etc.), or (2) the nature of the food product placed inside the dryer (surface area, constituent orientation, cellular structure, type and concentration of solutes).

1.12 SOME USEFUL BOOKS

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3. Earle, R.L. (1983) Unit Operations in Food Processing. Pergamon Press, Oxford.
4. Watson, F.L. and Harper, J.C. (1988) Elements of Food Engineering. Van Nostrand Reinhold, New York.
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UNIT 2 MOISTURE CONTENT AND EQUILIBRIUM MOISTURE CONTENT

Structure

2.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the importance of water in food preservation and its related issues;
- understand the importance of moisture content in food materials & methods of their determination and control; and
- understand equilibrium moisture content (EMC), its importance in food processing operations and methods of determination of EMC.

2.1 INTRODUCTION

Water is abundant in all living things and, consequently, in almost all foods, unless steps have been taken to remove it. It is essential for life, even though it contributes no calories to the diet. Water also greatly affects the texture of foods, as can be seen when comparing grapes and raisins (dried grapes), or fresh and wilted green leafy vegetables.

Almost all food processing techniques involve the use of water or modification of water in some form. Further, because micro-organisms cannot grow without water, the water content has a significant effect on the keeping quality of a food. This explains why freezing, dehydration, or concentration of foods increases shelf life and inhibits microbial growth.

Water is important as a solvent or dispersing medium, dissolving small molecules to form true solutions and dispersing larger molecules to form colloidal solutions. Acids and bases ionize in water, and water is also necessary for many enzymes to catalyze and chemical reactions to occur, including hydrolysis of compounds such as sugars. It is also important as a heating and cooling medium and as a cleansing agent.

2.2 CHEMISTRY OF WATER

The chemical formula of water is H_2O. Water contains strong covalent bonds, which hold the two hydrogen and one oxygen atoms together. The oxygen can be regarded as being at the center of a tetrahedron, with a bond angle of 105° between the two hydrogen atoms in liquid water and a larger angle of 109° 6' between the hydrogen atoms in ice.

The bonds between oxygen and each hydrogen atom are polar, having a 40% partial ionic character. This means that the outer shell electrons are unequally shared between the oxygen and hydrogen atoms, the oxygen atom attracting them more strongly than each hydrogen atom. As a result, each hydrogen atom is slightly positively charged and each oxygen atom is slightly negatively charged. They are therefore, able to form hydrogen bonds.

2.3 PROPERTIES OF WATER

2.3.1 Specific Heat

Specific heat is the energy required to raise the temperature of unit quantity of water by unit temperature and is the same whether heating water or ice. It is relatively high as compared to other substances, due to the hydrogen bonds. The unit of specific heat in SI system is $J\ Kg^{-1}\ K^{-1}$.

2.3.2 Latent Heat

Latent heat is the amount of heat uptake by unit quantity of water to change its state (liquid to solid & vice versa or liquid to vapour & vice versa) without any change in its temperature.

Latent heat of Fusion

It is the energy required to convert unit quantity of ice to water at freezing point and the unit is J/g of ice at the freezing point.

Latent Heat of Vaporization

It is the energy required to convert unit quantity of water to vapour at boiling point and is expressed in J for 1 g of water at the boiling point.

The specific and latent heats of water are all fairly high as compared to most other substances, and this is an important consideration when water is used as a medium of heat transfer. It takes considerable energy to heat water, and that energy is then available to be transferred to the food. Foods heated in water are slow to heat. Water also must take up considerable heat to evaporate. It takes heat from its surroundings; thus it is a good cooling agent.

2.3.3 Vapour Pressure

If a puddle of water is left on the ground for a day or two, it will dry up because the liquid evaporates. The water does not boil, but individual water molecules gain enough energy to escape from the liquid as vapour. Over time, an open, small pool of water will dry up in this way. If the liquid is in a closed container, at equilibrium, some molecules are always evaporating and vapour molecules are condensing, so there is no overall change in the system. The vapour (gaseous) molecules that have escaped from the liquid state exert a pressure on the surface of the liquid known as the vapour pressure.

When the vapour pressure difference is high, the liquid evaporates (is vaporized) easily and many molecules exist in the vapour state; the boiling point is low. Conversely, a low vapour pressure difference indicates that the liquid does not vaporize easily and that there are few molecules existing in the vapour state. There is a higher boiling point for these liquids. When the vapour pressure reaches the external pressure, the liquid boils.

The vapour pressure difference increases with increasing temperature. At high temperatures, the molecules have more energy and it is easier for them to overcome the forces holding them within the liquid and to vaporize, so there are more molecules in the vapour state.

The vapour pressure decreases with addition of solutes, such as salts or sugars. In effect, the solutes dilute the water; therefore, there are less water molecules (in the same volume) available to vaporize and, thus, there will be fewer in the vapour state, and the vapour pressure will be lower. There is also attraction to the solutes, which limits evaporation.

2.3.4 Boiling Point

Anything that lowers the vapour pressure increases the boiling point. This is due to the fact that the vapour pressure is lowered at a particular temperature, more energy must be put in; in other words, the temperature must be raised to increase the vapour pressure again. The external pressure does not change if salts or sugars are added, but it is harder for the molecules to vaporize so the temperature at which the vapour pressure is the same as the external pressure (boiling point) will be higher. One mole of sucrose elevates the boiling point by 0.52°C, and one mole of salt elevates the boiling point by 1.04°C. Salt has double the effect of sucrose because it is ionized, and for every mole of salt, there is one mole of sodium ions and one mole of chloride ions. Salts and sugars decrease the freezing point of water in a similar fashion.

If the external pressure is increased by heating in a pressure cooker or retort (commercial pressure cooker), the boiling point increases, and a shorter time period than normal is required to process the product (the basis of preserving food by canning). For example, food may be heated in cans in retorts, and the steam pressure is increased to give a boiling point in the range of 115-121°C. Conversely, if the external pressure is decreased, for example, at high altitude, water boils at a lower temperature, and requires a longer amount of time to process canned product.

2.3.5 Water as a Dispensing Medium

Substances can be dissolved, dispersed or suspended in water, depending on their particle size and solubility. Water dissolves small molecules such as salts or sugars or water-soluble vitamins to form a true solution, which may be either ionic or molecular.

Solution

An ionic solution is formed by dissolving substances, which ionize in water, such as salts, acids, or bases forming ionic solution. Taking sodium chloride as an example, the solid contains sodium (Na^+) and chloride (Cl^-) ions held together by ionic bonds. When placed in water, the water molecules reduce the attractive forces between the oppositely charged ions, the ionic bonds are broken, and the individual ions become surrounded by water molecules, or hydrated.

Polar molecules such as sugars, which are associated by hydrogen bonding, dissolve to form molecular solutions. When a sugar crystal is dissolved, hydrogen bond interchange takes place and the hydrogen bonds between the polar hydroxyl groups of the sugar molecules are broken and replaced by hydrogen bonds between water and sugar molecules. Thus, the sugar crystal is gradually hydrated, each sugar molecule being surrounded by water molecules.

Colloidal Dispersion

Molecules that are too big to form true solutions can be dispersed in water, depending on their size. Those with a particle size range of 1 nm to 100 nm are dispersed to form a colloidal dispersion or a sol. Examples of such molecules include cellulose, cooked starch, pectic substances and some food proteins. Colloidal dispersions are often unstable; thus proper care must be taken to stabilize them where necessary if they occur in food products. They are particularly unstable to such factors as heating, freezing, or pH change. Changing the conditions in a stable dispersion can cause precipitation or gelation; this is desirable in some cases, for example when making pectin jellies.

Sol is a colloid that pours – a two phase system with a solid dispersed phase in a liquid continuous phase, for example a hot sauce. A gel is also a two phase system, but it is an elastic solid with a liquid dispersed phase in a solid continuous phase.

Suspension

Particles that are larger than 100 nm are too large to form a colloidal dispersion. They form a suspension when mixed with water. The particles in a suspension separate out over time, whereas no such separation is observed with colloidal dispersions. An example of a suspension would be uncooked starch grains in water. They can be suspended throughout the liquid by stirring, but if left undisturbed, they will settle down, and sediment will be observed at the bottom of the container.

2.4 TYPES OF WATER AND WATER ACTIVITY

2.4.1 Types of Water

Water is abundant in all living things and, consequently, in almost all foods, unless steps have been taken to remove it. Most natural fresh foods contain 70% of their weight, or greater of water, and fruits and vegetables contain upto 95% or greater water. Water that can be extracted easily from foods by squeezing, or cutting or pressing is known as free water, whereas water that cannot be extracted easily is termed bound water.

Bound water is usually defined in terms of the way it is measured; different methods of measurement give different values for bound water in a particular food. Many food constituents can bind or hold on to water molecules, so that they cannot be easily removed and they do not behave like liquid water. Some characteristics of bound water include the following:

- It is not free to act as a solvent for salts and sugars.
- It can be frozen only at very low temperatures (below the freezing point of water).
- It exhibits essentially no vapour pressure.
- Its density is greater than that of free water.
- It has more structural bonding than liquid water, thus it is unable to act as a solvent.

Water may also be entrapped in foods such as pectin gels, fruits, vegetables and so on. Entrapped water is immobilized in capillaries or cells, but if released by cutting or damage, it is free to flow. Entrapped water has the properties of free water and has no properties of bound water.

2.4.2 Water Activity (A_w)

Water activity or A_w, is a ratio of the vapour pressure of water in a solution (P_s) as compared to the vapour pressure of pure water (P_w) at a given temperature.

$$A_w = \frac{P_s}{P_w} \qquad (2.1)$$

Living tissues require sufficient levels of water to maintain turgor, and the A_w must be high. However, micro-organisms such as bacteria, mould and yeast multiply at high A_w. Because their growth must be controlled, prevention techniques against the spoilage these micro-organisms cause take into account the water activity of the food.

Jam, jellies and preserves and pickles are prepared using a high concentration of sugar, and salt. Sugar and salt are both effective preservatives due to the fact that they lower A_w. Salt lowers the A_w more effectively than sugar due to its chemical structure that ionizes and attracts water.

Properties of Food that Control the Water Activity

Certain properties of the food and the way water interacts with the components of a food result in different degree of binding or tying up of the water. The more tightly water is bound; the lower is its water activity (A_w). The three major physical effects that lower water activity are:

1. **Colligative effect**: When a solid solute dissolves in water, it interacts with water in three dimensions through dipole – dipole, ionic and hydrogen bonds. These interactions affect the properties of water based on the amount of the added molecules relative to the amount of water molecules present. This interaction is called a colligative effect.

2. **Capillary effect**: A second effect that depresses water activity is the capillary effect. The vapour pressure of water above a curved liquid meniscus is less than that of pure water because of changes in the hydrogen bonding between water molecules as a result of the surface curvature. Since foods have a myriad of capillaries, some lowering of the water activity should result. The Kelvin equation predicts this lowering by:

$$A_w = \exp - \frac{2\gamma_s \cos\theta \overline{V_L}}{rRT} \qquad (2.2)$$

where,

γ_s = surface tension of liquid in a pore,

θ = wetting angle,

$\overline{V_L}$ = molar volume of liquid in cm^3/mole,

r = capillary radius,

R = gas constant (8.314 x 10^7 ergs/°K mole) and,

T = °K.

Most pores in foods are in the 10 – 300 μm range. Assuming complete wetting (cos θ) and pure water (γ_s=72.3 dyne/cm) in the pores, the Kelvin equation predicts an A_w in the range of 0.989 – 0.999. Thus the A_w is lowered very little by capillarity. However, 5 – 7% of the pore volume in foods is of pores of 0.01 – 0.001 μm, which lowers the A_w above the vapour space to values of 0.899 – 0.34. Thus, smaller capillaries have a greater effect on lowering of A_w.

3. **Surface interaction**: Finally, water directly interacts with other chemical groups on molecules through dipole – dipole force, ionic bonds (H_3O^+ or OH^-), van der Walls forces (hydrophobic bond), and the hydrogen bond. These water molecules, so bound, require extra energy to be transferred from the liquid to the vapour state and thus are less free to the vapour, resulting in reduced A_w. This effect is more pronounced at low A_w. The point of critical importance is the monolayer. This is the moisture content at each polar and ionic group has a water molecule bound to it, to form the start of a liquid like phase. Reactions which depend on water as a reaction phase medium do not occur below this moisture content at appreciable rates.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe the importance of water in food systems.

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2. Write short notes on the following:

a) Vapour pressure b) Boiling point

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3. Differentiate between the following

a) Ionic and molecular solution b) Colloid and suspension

c) Free and bound moisture

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4. Define water activity (A_w).

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5. Enlist the properties of food that control water activity. Explain any one.

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2.5 ROLE OF WATER IN FOOD PRESERVATION AND SHELF LIFE OF FOODS

Control of the water level in foods is an important aspect of food quality. Foods may be more desirable either crispy or dry. Freezing and drying are common food preservation processes that are used to extend the shelf life of foods because they render water unavailable for pathogenic or spoilage bacteria.

2.6 WATER HARDNESS AND TREATMENTS

The hardness of water is measured in parts per million of calcium carbonate. Soft water contains 0-60 ppm and has no mineral salts. It contains some organic matter. Hard water contains more than 60 ppm dissolved salts. Water may exhibit temporary hardness due to iron, or calcium and magnesium bicarbonate ions [$Ca(HCO_3)_2$ and $Mg(HCO_3)_2$]. The water may be softened as it is boiled (soluble bicarbonates precipitate in boiling and leave deposits or scales) and insoluble carbonates may be removed from the water.

Permanent hardness of water cannot be removed by boiling as it contains either calcium or magnesium sulphates ($CaSO_4$ or $MgSO_4$) as well as other salts that are not precipitated by boiling. Permanent hardness is removed by the use of chemical softeners. Hard water exhibits less cleaning effectiveness than soft water due to the formation of insoluble calcium and magnesium salts with soap. The use of detergents rather than soap prevents this formation.

Water has a pH of 7 when it is neither acidic nor alkaline. Water is acidic if the pH is less than 7 and alkaline if the pH is more than 7. Tap water displays a variance on either side of neutral. It may be slightly alkaline or slightly acidic depending on the source. Hard water has a pH of upto 8.5. Chlorinated water is that which has had chlorine added to kill or inhibit the growth of microorganisms. Manufacturing or processing plants may require potable soft water of good quality to prevent turbidity, off-colour and off-flavour in food products. The use of tap water, which is not sufficiently soft, is not advisable for use in food products.

2.7 MOISTURE MEASUREMENT TECHNIQUES

There are several methods for determination of moisture content of food materials. The choice of method depends on many factors, such as (1) the form in which water is present in the product, (2) the relative amount of water present, (3) the rapidity of determination, (4) accuracy of method, (5) product's nature whether easily oxidized or decomposed, and (6) cost of equipment used.

Moisture content is determined mainly by two methods, (1) direct, also called primary and (2) indirect, also called as secondary methods. The accuracy of moisture content determination by direct methods is high, but time consuming. Indirect methods are faster and mostly employ the electrical properties of the grain.

2.7.1 Direct Methods

Air Oven Method

2-3 / 25-30 grams of ground / unground representative sample is placed in an air oven at a temperature of 130°C / 100°C for 2-3/72-96 hours. The moisture content of the samples is measured by the difference in initial and final weights of the sample. The selection of sample size, temperature and duration may be different for different materials.

Vacuum Oven Method

2-3 grams of representative sample of ground material is placed in a vacuum oven (25 mm vacuum) and dried at 100°C for 72-96 hours. Here also the moisture content is measured by the difference in initial and final weights of the sample.

Brown-Duvel Fractional Distillation Method

100 grams of the sample is mixed along with 150 ml of mineral oil and boiled. Moisture from the sample is evaporated, collected, condensed and measured in a graduated cylinder. The time required for moisture determination is about 30 minutes.

Infra-red Method

Moisture content is directly measured by evaporation of water from the sample with an infra red heating lamp. The infra red lamp evaporates the moisture of the product and the difference in initial and final weights gives a measure of the amount of moisture in the food.

2.7.2 Indirect Methods

Electrical Resistance Method

The electrical conductivity or resistance of a product depends upon its moisture content. This principle is employed in resistance measuring devices. The food sample is kept in a container at a particular compaction and temperature. The electrical resistance is then measured across it and the resistance is calibrated to give the moisture content.

Dielectric Method

Similar to the electrical resistance method, but here the capacitance of the sample is measured when a high frequency current is passed through the sample placed between the two plates of the condenser.

Chemical Method

The removal of water by strong desiccants ($CaCl_2$) is caused by the vapour pressure gradients. The moisture moves from the samples to the drying agent, due to vapour pressure gradient between the sample and the desiccant. The hydration of salt is accompanied by evolution of heat. The heat of evolution helps in driving the water out of the samples. Calcium chloride, when heated to redness reacts with superheated steam to form HCl and Calcium hydroxide.

$$CaCl_2 + H_2O \rightarrow Ca(OH)_2 + 2HCl \qquad (2.3)$$

2.8 EMC AND ITS RELEVANCE TO FOOD PRESERVATION

Most of the food products absorb or loose moisture from environment. When the ambient temperature rises and humidity of air decreases, the water present in foods vaporizes. Consequently the food loses moisture which results in desiccation / drying. In other words, if the vapour pressure of water present in the foods is more than the vapour pressure of moisture in air, the water present in food vaporizes and diffuses into the atmosphere. Alternatively, if the vapour pressure of water in the foods is less than the atmospheric vapour pressure, foods will absorb moisture from the atmosphere. This property of gaining or loosing of moisture as per the atmospheric conditions is known as hygroscopicity.

The moisture content attained by foods with respect to the set of atmospheric temperature and relative humidity is called the equilibrium moisture content (EMC) of the food. In such condition, the food moisture is in equilibrium with the surrounding air.

2.8.1 Importance of EMC

EMC is of particular importance for drying and storage of food materials. The usefulness of EMC are:

i) EMC gives an idea whether the food material will gain or lose moisture under a particular atmospheric condition.

ii) It gives an idea about rate of moisture removal.

iii) EMC helps to determine drying characteristics.

iv) With the knowledge of EMC, it can be predicted as to what final moisture level a product can be dried with the heated air.

2.8.2 Hysteresis Effect

When food products in the process of loosing moisture attains equilibrium moisture content with the surroundings, the EMC is known as desorption EMC. But when a dry product gains moisture from the surroundings and attains EMC, that value of EMC is said to be adsorption EMC. At some relative humidity and temperature level there is a meaningful difference between the desorption and adsorption EMC values. The desorption EMC values are higher than the adsorption EMC values. The differences between desorption and an adsorption curve is known as hysteresis effect (Figure 2.1). As seen from the figure, the differences between the adsorption and desorption values are more significant for the intermediate range of moisture contents.

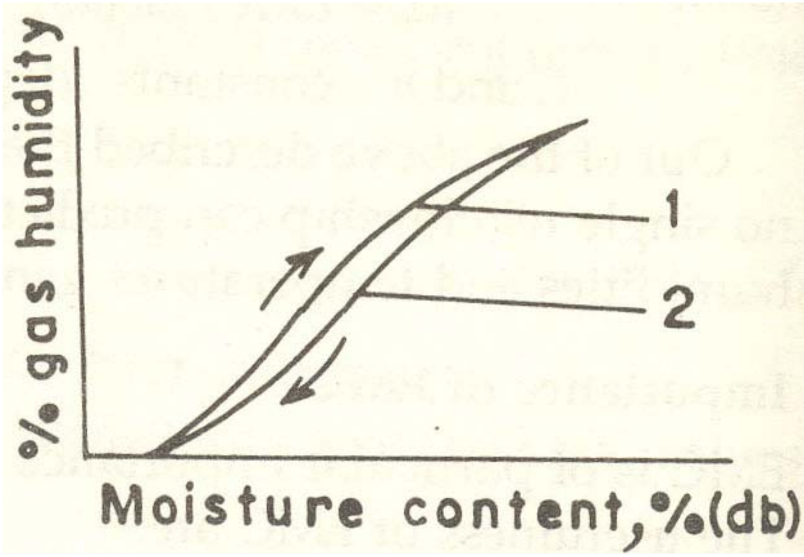

Figure 2.1: Hysteresis effect: 1) Adsorption EMC curve, 2) Desorption EMC curve

2.9 EMC DETERMINATION METHODS

The methods of determination of EMC of food materials can be categorized into two: (1) static method and (2) dynamic method. In the static method, food is left in the air with known temperature and humidity until it attains equilibrium, while in the dynamic method the conditioned air is agitated or moved by mechanical means and the food attains equilibrium condition further.

2.9.1 Static Method

In static methods, to bring the atmospheric air to desired relative humidity levels different concentrations of acids or salt solutions are used. Static methods are generally time consuming, and to bring the food to equilibrium condition, 3 – 4 weeks are required. Thus in case of high humidity and high temperature conditions, chances of attack of moulds are high. Decomposition and change in food structure is also possible. It is essential to maintain the required humidity and temperature conditions of air throughout the test period. Temperature is normally maintained using an incubator or oven whereas relative humidity is maintained using acid/salt solutions in desiccators.

2.9.2 Dynamic Method

Desorption Method

The property of dry air to absorb moisture from moist foods is employed. Most foods are put in an airtight container. When the air comes in equilibrium to food its relative humidity is measured by a hygrometer. Since the container has small quantity of air, it reaches equilibrium with the food within a short period.

Isotenoscopic Method

This method also employs absorption of moisture by dry air to determine EMC of the food material. But in this method arrangement is available to measure directly the vapour pressure exerted by the moist foods (Figure 2.2). The food sample is kept in a conical flask.

Isotenoscope is a U tube filled with the liquid of negligible vapour pressure. The arms of the tube has an enlarged section above the level of liquid to prevent drawing of liquid out of the tube while evacuating or readmitting air to the flask. The isotenoscope is connected to a vacuum pump through a vacuum storage jar. Atmospheric pressure can be brought back into this jar by means of a valve'V_1'. The 'V_2' is a shut off valve connecting closed while all air is evacuated from the flask, the vacuum storage jar, and from the system. Under this condition, vapour pressure builds up in the flask, which forces the liquid in the two arms of the isotenoscope to dissimilar level. Bleeding a small amout of air into the vacuum storage jar then equalizes the level of the liquid. This equalization pressure is continued until vapour pressure buildup in the flask has reached the maximum for the temperature of water bath. Valve 'V_2' is then closed and the absolute pressure indicated in the manometer is read. The isotenoscope is removed from the flask and a properly weighed stopper closes the flask. The weight of flask with sample is recorded to determine sample moisture content.

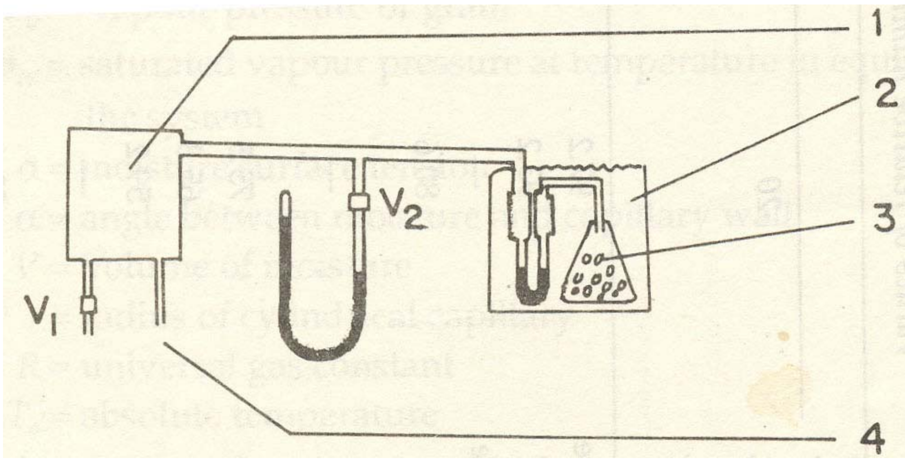

Figure 2.2: Schematic diagram of an isotenoscope: 1) Vacuum storage jar, 2) Constant temperature water bath, 3) Sample flask and 4) Vacuum pump

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is hardness of water and how can it be removed?

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2. Define EMC and hysteresis.

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3. Enlist the different moisture measurement techniques and explain any one method.

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4. Enlist the different EMC measurement techniques and explain any one method.

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2.10 LET US SUM UP

Let us now recapitulate the information presented in this unit. Water is an important material in the food processing activities. It is necessary to take into account the behaviour and properties of water while planning for any food processing activity. Water in food products may be present in bound, entrapped and free forms. Water contained in a food material is expressed in terms of moisture content on either dry or wet weight basis. Another way to express the moisture content in a food material is to determine its water activity. Higher the free water content, higher is the water activity at a given temperature. Water activity and spoilage of a food material are positively correlated. Methods of moisture content determination could be direct as well as indirect. Oven method is one of the direct methods, which is accurate but time consuming. Measurement of electrical conductivity or dielectric constant of a food material is quick but indirect method of moisture content determination. A food material, when placed in the air of specific temperature and humidity, attains moisture content, which is called its equilibrium moisture content (EMC). Depending on whether the food material gained the moisture or lost it to attain the EMC, the two values may be different and this behaviour of food material is known as Hysteresis. EMC determined can be through either static or dynamic methods. Isotenoscope is an apparatus to determine EMC of food materials dynamically.

2.11 KEY WORDS

Moisture content : It indicates the amount of free moisture in any material.

Water activity : Water activity or A_w, is a ratio of the vapour pressure of water in a solution (P_s) as compared to the vapour pressure of pure water (P_w) at a given temperature.

Hygroscopicity : It is the property of gaining or loosing of moisture (due to vapour pressure difference) as per the atmospheric conditions.

Specific heat : Specific heat is the energy required to raise the temperature of unit quantity of water by unit temperature and is the same whether heating water or ice.

Latent heat of fusion : It is the energy required to convert unit quantity of ice to water at freezing point and the unit is J/g of ice at the freezing point.

Colloidal dispersion : Molecules that are too big to form true solutions can be dispersed in water, depending on their size and the mixture is called as colloidal dispersion.

Suspension : Particles that are larger than 100 nm are too large to form a colloidal dispersion. Those form a suspension when mixed with water. The suspended particles settles down if the suspension is left undisturbed.

Free water : Water that can be extracted easily from foods by squeezing, or cutting or pressing.

Bound water : Water that cannot be extracted easily is termed bound water.

Entrapped water : Water bound by food constituents so that they cannot be easily removed and they do not behave like liquid water.

EMC : The moisture content attained by foods with respect to the set of atmospheric temperature and relative humidity

Hysteresis : The difference between the adsorption and desorption EMC at any given temperature and relative humidity.

Isotenoscope : Equipment used for measuring dynamic EMC

2.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Foods are living systems where water is the basis of several biochemical processes including the growth of micro-organisms. Foods with high water content have, therefore, limited usable life. Water content in foods needs to be regulated to a manageable level for achieving the intended shelf-life.

2. a) Vapour pressure: Water in air normally exists in vapour form. As you know, air is composed of mainly oxygen, nitrogen, carbon di oxide, water vapour and other gases in small amounts. Each of these constituents of air contributes to the atmospheric pressure depending upon their relative magnitudes. Water vapour also contributes a small fraction to the pressure.

   b) Boiling point: Boiling point is the temperature at which water starts boiling. At mean sea level, the boiling point for pure water is 100°C or 373°K.

3. a) Ionic solutions have charged particles like anions and cations. Molecular solutions have the solutes in molecular form, which are not electrically charged.

   b) Colloid is a mixture of liquid and solid particles, which are so fine that they exhibit Brownian movement. The colloids remain in perpetual suspension. A true suspension retains its apparent homogeneity for a short time after stirring. The suspended particles then settle down.

   c) Free water is the water in a food material that can be extracted easily by squeezing, or cutting or pressing, whereas the water that cannot be extracted easily is termed bound water.

4. Water activity or A_w, is a ratio of the vapour pressure of water in a solution (P_s) as compared to the vapour pressure of pure water (P_w) at a given temperature.

$$A_w = \frac{P_s}{P_w}$$

5. The properties of food that control water activity are:

   a) Colligative effect
   b) Capillary effect
   c) Surface interaction

   Colligative effect: When a solid solute dissolves in water, it interacts with water in three dimensions through dipole – dipole, ionic and hydrogen bonds. These interactions affect the properties of water based on the amount of the added molecules relative to the amount of water molecules present. This interaction is called a colligative effect.

Check Your Progress Exercise 2

1. The hardness of water is measured in parts per million of calcium carbonate. The water may be softened as it is boiled (soluble bicarbonates

precipitate in boiling and leave deposits or scales) and insoluble carbonates may be removed from the water.

2. EMC: The moisture content attained by foods with respect to the set of atmospheric temperature and relative humidity is called the equilibrium moisture content (EMC) of the food.

   Hysteresis: At a relative humidity and temperature level there is a meaningful difference between the desorption and adsorption EMC values. The desorption EMC values are higher than the adsorption EMC values. The differences between desorption and an adsorption curve is known as hysteresis effect.

3. Different moisture measurement techniques are:

   Direct methods:

   a) Air oven method
   b) Vacuum oven method
   c) Brown-Duvel fractional distillation method
   d) Infra-red method

   Indirect methods:

   a) Electrical resistance method
   b) Dielectric method
   c) Chemical method

   Electrical resistance method: In this method, the food sample is kept in a container at a particular compaction and temperature. The electrical resistance is then measured across it and the resistance is calibrated to give the moisture content.

4. Different EMC measurement techniques are:

   i) Static method
   ii) Dynamic method

      a) Desorption method
      b) Isotenoscopic method

   Desorption method: Most foods are put in an airtight container. When the air comes in equilibrium to food its relative humidity is measured by a hygrometer.

2.13 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

UNIT 3 CLEANING AND GRADING

Structure

3.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the importance of cleaning and grading in the food processing operations;
- know the cleaning and grading devices and their operating principles; and
- should be able to select a suitable cleaning and grading device for any given operation.

3.1 INTRODUCTION

Cleaning and grading are important post harvest operations undertaken to remove foreign and undesirable materials from the produce and to separate the produce into various fractions. The comparative commercial value of food products is dependent on their grade factors. These grade factors further depend upon (1) physical characteristics like size, shape, moisture content, colour, etc., (2) chemical characteristics like odour, and (3) biological factors like insect damage.

It is difficult to clearly differentiate between the processes of cleaning and grading because these are carried out simultaneously with the common procedures. The operation of cleaning and grading of the products are performed by exploiting the differences in engineering properties of the materials. These products may be used either for food or seed purposes.

3.2 DEFINITIONS AND OBJECTIVES OF CLEANING

Cleaning and grading both are the processes of separation. Cleaning generally means the removal of foreign and undesirable material from desired grains / products. The objective is to reduce the cost of further handling as unnecessary fraction would have been separated. Besides the clean material fetches higher prices. In this sense, cleaning is a value addition operation.

Grading refers to the classification of the cleaned product into various quality functions depending upon the commercial value and usage. For example, separating ripe tomatoes from unripe ones. This also is a value addition operation.

3.3 METHODS OF CLEANING

The undesirable material from the mixture could be removed by wet, dry or a combination of wet and dry methods.

3.3.1 Wet Method

The wet method of cleaning consists of spraying clean water over the mixture in a trough of water to remove the undesirables. Then the desirable washed material is appropriately dried to remove the adhering moisture. It is important in this process that the desirable material should not get affected by the washing treatment and that the water used for washing is clean so as not to leave any residue after washing and drying.

3.3.2 Dry Method

The dry methods of cleaning are based on the specific properties of the constituents of the mixture such as:

1. Size
2. Shape
3. Specific gravity or weight
4. Surface roughness
5. Aerodynamic properties
6. Ferro-magnetic properties
7. Colour
8. Electrical properties

Cleaners based upon size

Screen cleaners/graders: It performs the separation according to size alone. The mixture of grain and foreign matter is dropped on a screening surface, which is vibrated either manually or mechanically. A single screen can make the separation into two fractions. The screening unit may be composed of two or more screens as per the cleaning requirement.

A hand-operated screen cleaner (Figure 3.1) is made of mild steel. The separation takes place due to difference in size of grain and foreign matter. The cleaner is operated by hanging on an elevated point with the help of four ropes. Produce is fed on the screening surface in batches. The screens can be changed as per the grain to be handled. The cleaner is swung to and fro till all the grain is screened. The cleaned grain is retained by the bottom sieve which can be discharged by pulling a spring loaded shutter. Impurities of larger size, stubbles, chaff etc. are retained on the top sieve and can be removed easily. Down stream from the bottom sieve consists of dust, dirt, brokens, shrivelled produce etc. drop down during the operation.

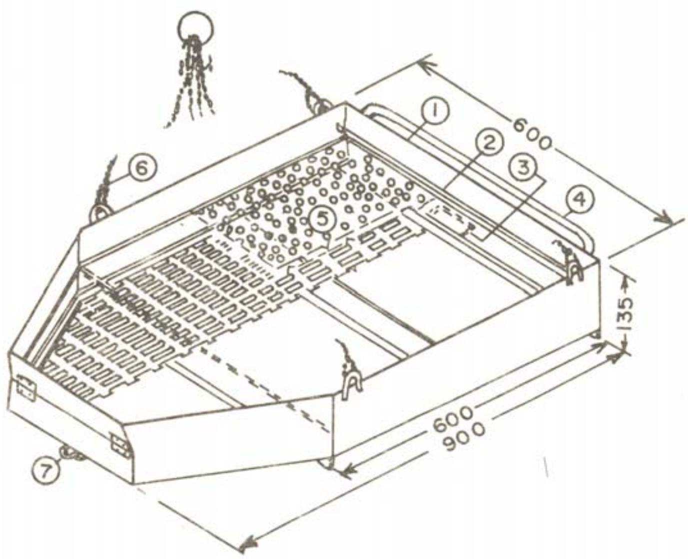

Figure 3.1: Hand operated double screen grain cleaner. 1) frame 2) draper rod 3) screen handle 4) handle 5) scalper and grader screens 6) rope attachment 7) shutter opening attachment

Air screen cleaners: The screens used in combination with air blast performs satisfactory cleaning and separation operations for most of the granular materials. The air-screen cleaner uses three cleaning systems: blowing or aspiration, scalping screens and grading lower screens. The air-screen grain cleaner can be classified in two distinct types: *(i)* vibratory screen, *(ii)* rotary screen, based on movement of the screening surface.

Vibratory air-screen cleaner: The screening unit is composed of double or multiple (up to 8 number) screens. These screens are tightened together and suspended by hangers in such a manner that these have horizontal oscillating motion and slightly vertical motion. These two motions in combination move the grain down the screen and at the same time toss sufficiently above the screen so that the bed of grain is properly stirred. The slope of the screen is adjustable to control the rate of downward travel of the grain. The screens are available in various shapes like; round, triangular or slotted holes as discussed earlier. Sometimes the holes of the screen are clogged when the machine makes fine degree of sorting. To avoid the clogging, the screens are generally fitted with a brush which moves under the screen and pushes the clogged material back through the screen. Other such devices can also be used for this purpose. A simple vibratory type air-screen cleaner is shown in Fig. 3.2.

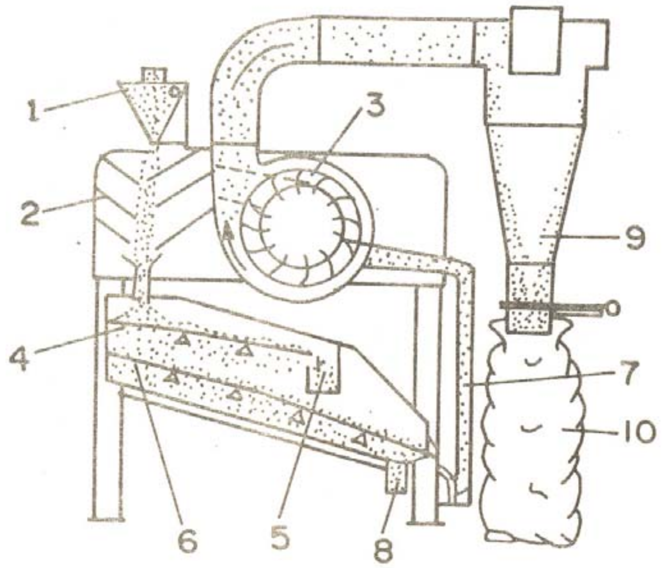

Figure 3.2: Schematic diagram of a vibratory air screen cleaner. 1) Feed Hopper, 2) Baffle plate, 3) Blower, 4) Upper screen, 5) Discharge channel, 6) Sand sifter, 7) Ascending separator, 8) Discharge funnel, 9) Centriclone, 10) Dust Bag

Rotary screen cleaner: The rotary screen cleaner has normally circular decks. Their motion is circular in horizontal plane. These have either single or double drum. A single drum rotary screen cleaner is shown in Figure 3.3. The machine consists of a rotary screen, aspirator and hopper and equipped with an electric motor, which gives drive to the rotary screen and the aspirator. The mixture is fed into the hopper. The sound grains pass through the screen perforation into the centre of the screen drum, whereas oversized material is retained above and pass out though an outlet. The sound grains come out at the centre side of the screen drum rotating at low speed and fall onto the vibratory screen which remove the dirt particles. The light particles like straw and dust are sucked away by the aspirator and discharged through the aspirator outlet. The cleaned grains are delivered through the discharge chute.

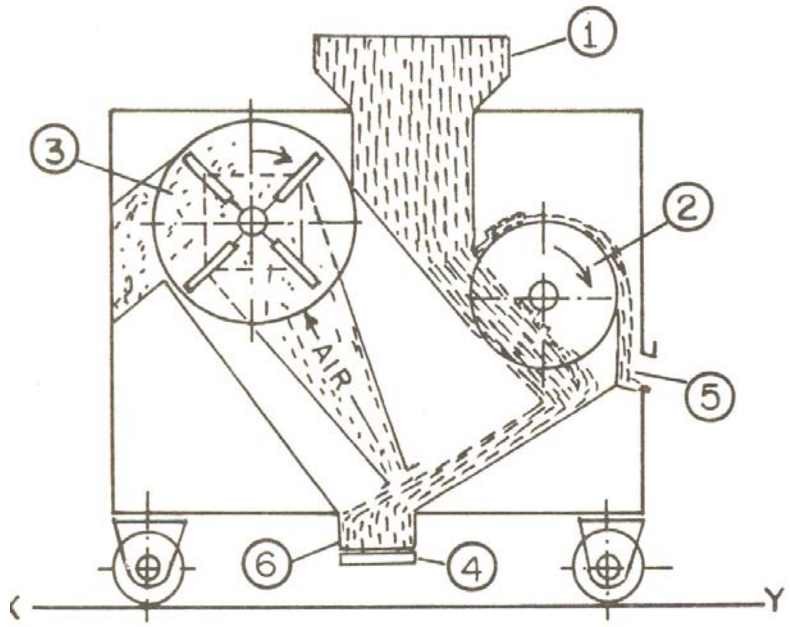

Figure 3.3: Diagram of a single drum rotary screen cleaner. 1) Feed hopper, 2) Rotary screen, 3) Aspirator, 4) Discharge chute, 5) Over size foreign matter outlet, 6) Vibratory screen

Specific gravity cleaners

The specific gravity separator makes the separation according to difference in density or specific gravity of the materials. This separator works on two principles, (1) the characteristics of grains to flow down over an inclined surface, (2) the floatation of the particle due to upward movement of air.

The main part of the device is a triangular-shaped perforated deck. The deck is properly baffled underneath to ensure uniform distribution of air over it. The pressure or terminal velocity of the air rising through the deck can be controlled very closely within a wide range (Figure 3.4).

The mixture of produce is fed into the feed box. The air is blown up through the porous deck surface and bed of the grain by a fan at such a rate that the material is partially lifted from contact with the deck surface. The lightest materials are lifted to the top of the stratified mass. The air does not lift the heavier particles. The stratified mass moves along the direction of conveyance due to oscillating motion of the deck and is discharged at the right edge of the deck.

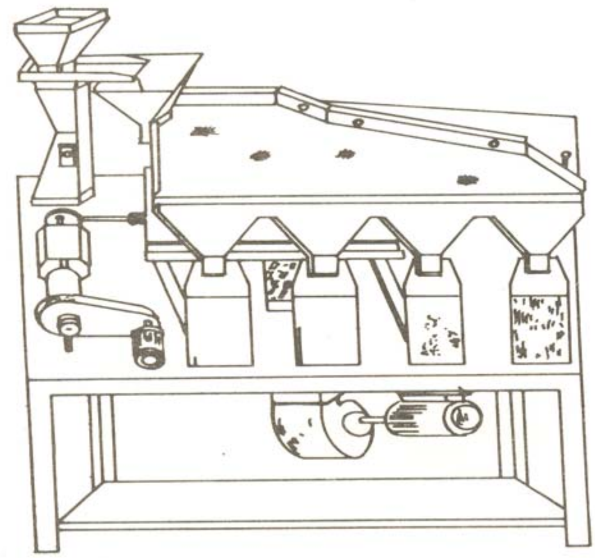

Figure 3.4: Specific gravity separator

Aerodynamic cleaners

The pneumatic separation is based on the difference in aerodynamic properties of various constituents of the mixture. The aerodynamic properties of a particle depend upon its shape, size, density, surface and orientation with respect to air current. Both the aspirator and the pneumatic separator use terminal velocity of the grain to separate different fractions. This refers to the velocity of air required to suspend particles in a rising air current.

In a pneumatic separator, the fan is placed at the intake end of the machine, which creates higher pressure than the atmospheric pressure. The high pressure air blast separates the materials. The mixture of products is introduced into a confined rising air stream; the air current lifts the particles with low terminal velocities whereas the particles with higher terminal velocities than air velocity fall down. The air velocity can be adjusted by altering the speed of fan or by changing the opening of air inlet (Figure 3.5).

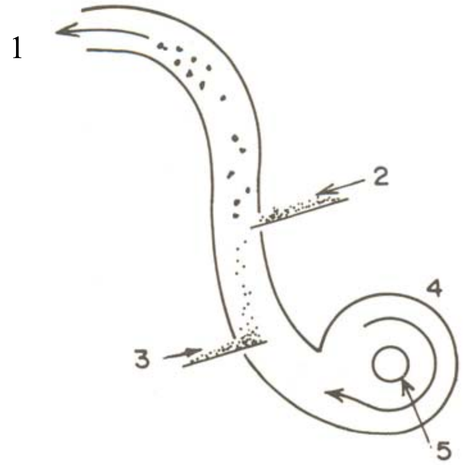

Figure 3.5: Diagram of a pneumatic separator. 1) Undersirable material removal, 2) Uniform feeder, 3) Clean grain outlet, 4) Centrifugal blower, 5) Control for air intake

3.4 METHODS OF SEPARATION

We often encounter mixtures of food materials, which need to be separated into different fractions for either subsequent marketing or processing. Fruits harvested from an orchard are normally of different sizes, which would fetch lower prices as compared to the graded fruits packed nicely. There are several similar situations where it is necessary to separate different fractions from a mixture. This separation could be achieved by utilizing one or more of the properties of the constituents of the mixture. The most common property is the size. The other properties normally utilized for separation are weight, specific gravity, surface roughness, optical properties and magnetic properties. The basic principles of the operation of different separators are being presented in the following sections.

3.4.1 Size Based Separators

The bulk food material such as a basket of fruits or vegetables is fed to a container from which the individual food items are segregated on the basis of their diameter or length or any other significant dimensions. In case of handy materials such as dry fruits and nuts, even oscillating sieves could be used for the separation. However, fresh fruits and vegetables get easily damaged, therefore, they need to be carefully handled. The relative motion between the food items and the separator is minimized. A grader for separating mangoes on size basis is shown in Figure 3.6. As you may note the fruits roll on the continuously diverging channel and, thus, the separation takes place.

Figure 3.6: Size based mango grader

3.4.2 Specific Gravity Separators

Some materials, when separated on size basis do not give the correct classification, for example, some groundnut pods may attain a particular size, the kernels in them remain immature. Obviously, such pods are not desirable and need to be separated from the pods that have bold kernels. This separation could be achieved by letting the mixture float in a fluid. Based on the specific gravity, the fractions will settle down differently. A cream separator in dairy processing is also categorized under specific gravity separators.

3.4.3 Colour Separators

The colour separator separates the fruits, vegetables or grains due to difference in colour or brightness. The colour separators are generally used for larger crop seeds like peas and beans. These seeds differ in colour because of varietal differences and also due to immaturity or disease. The mud balls and discoloured or defective seeds can be removed with the help of electronic separator. The material mixture is fed uniformly into the optical chamber of the separator.

Two photocells are fixed at a particular angle, which direct both beams to one point of the parabolic trajectory of the grains. A needle is placed on the other side, which is connected to a high voltage source (Figure 3.7). When a beam falls on a dark object through photoelectric cells, current is generated on the needle. The needle end receives a charge and imparts it to the dark seeds. The grains are then passed between two electrodes with a high potential difference between them. The seed is compared with a selected background or colour range, and is separated into two fractions according to difference in colour. Since this machine views each produce individually, the capacity is low.

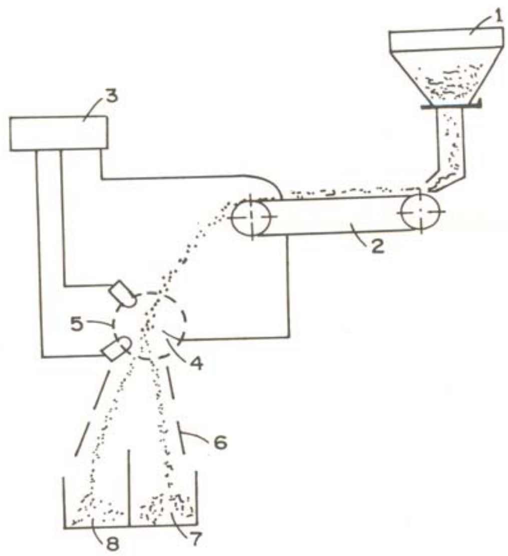

Figure 3.7: Schematic of a colour separator 1) hopper, 2) belt conveyor, 3) amplifier, 4) charging needle, 5) optical chamber, 6) deflecting electrodes, 7) foreign material, 8) desired material

3.4.4 Weight Based Separators

Certain food items are of regular shape or size. They are separated on weight basis. The food items are conveyed over a set of pan balances arranged in such a way that the lowest weight objects travels farthest. Heavier object tips the balances earlier and get collected in a trough. The lighter object passes on these balances and moves farther till the appropriate balance tips down and the object is picked up for separation into the correct class.

3.4.5 Magnetic Separators

The magnetic separator performs separation on the basis of surface texture and stickiness properties of the grain. Since the grains do not contain any free iron, therefore, are not attracted by the magnet. A selective pre-treatment of mixing finely ground iron powder to feed mass is given. The grain mixture is fed to a screw conveyor or other mixing device that tumbles and mixes the grain with a proportioned amount of water. Due to moisture, iron powder adheres to rough, cracked, broken and sticky seed coats. Moisture does not remain on smooth grains so no iron powder adheres to smooth surfaced grains.

The grain mixture is fed onto the top of a horizontal revolving magnetic drum, the smooth grains that are relatively free of powder fall along the drum simply by gravity. The materials with iron powder are attracted by the magnetic drum and stick to it and are removed by rotary brush or break in the magnetic field as shown in Figure 3.8.

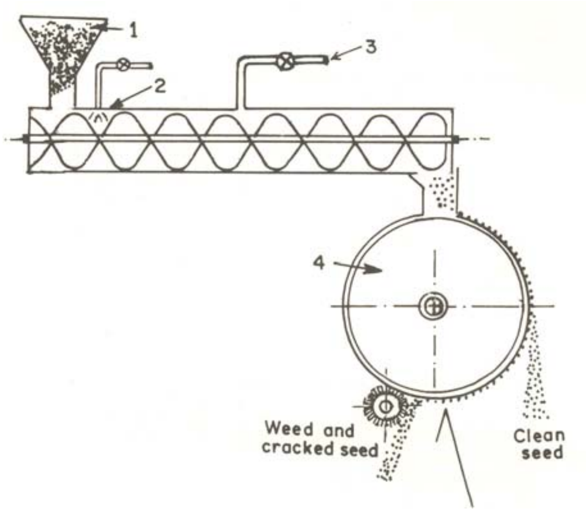

Figure 3.8: Magnetic Separator. 1) Feed hopper, 2) Water spray, 3) Iron powder mixing, 4) Magnetic drum.

3.4.6 Surface Texture/Roughness Separator

The mixture to be separated is fed over the centre of an inclined draper belt moving in upward direction. The round and smooth grains roll or slide down the draper at faster rate than the upward motion of the belt, and these are discharged in a hopper. The flat shape or rough surfaced particles are carried to the top of the inclined draper and dropped off into another hopper. (Figure 3.9). The belts of different degrees of roughness may be used as a draper for separate materials. If rolling tendencies of the grain are predominant, the rough canvas belt may be used. The smooth, plastic belt may be used in case sliding action is desired for the lower fraction. Feed rate, speed of draper and angle of inclination are other important variables for effective separation of dissimilar materials.

The feed rate is kept low enough to give opportunity to each grain for separation. The speed of the draper may be varied to simulate with the length of incline. The angle of inclination is adjusted to assure rolling or sliding of the desired lower fraction. To increase the capacity of the separator, number of belts may be used one above another in a single machine.

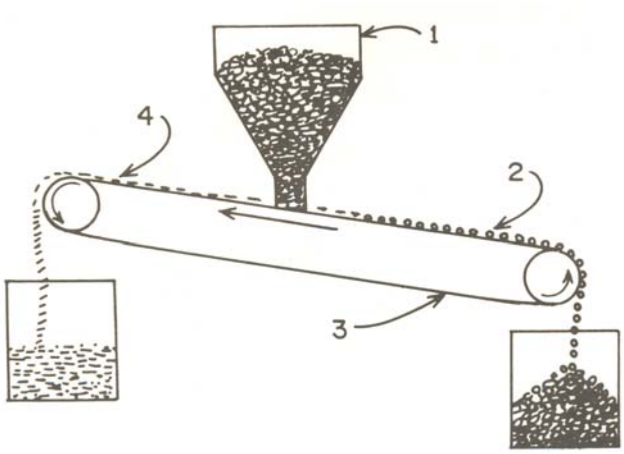

Figure 3.9: Inclined draper. 1) Feed hopper, 2) Round seed, 3) Canvas draper, 4) Flat seed/impurities.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define cleaning and grading.

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2. Enlist five different characteristics of foods that are used for its separation from unwanted materials.

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3. Describe the working principle of the following:

i) Air screen separator
ii) Inclined draper
iii) Pneumatic separator
iv) Colour sortor

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3.5 SCREENS

The basic purpose of any screen is to separate a mixture of particles / items of different sizes into two distinct fractions. These fractions are, (1) the - underflow, the particles that pass through the screen, and (2) the overflow or oversize, the materials that are retained over the screen. A screen can be termed as **ideal** screen that separates the mixture in such a way that the largest particle of underflow is just smaller than screen opening, while the smallest particle of overflow is just larger than the screen opening. But in practice a given screen does not gives perfect separation as stated above, and is called **actual** screen. The underflow may contain material coarser than screen size, whereas the overflow may contain particles smaller than screen size as shown in Figure 3.10.

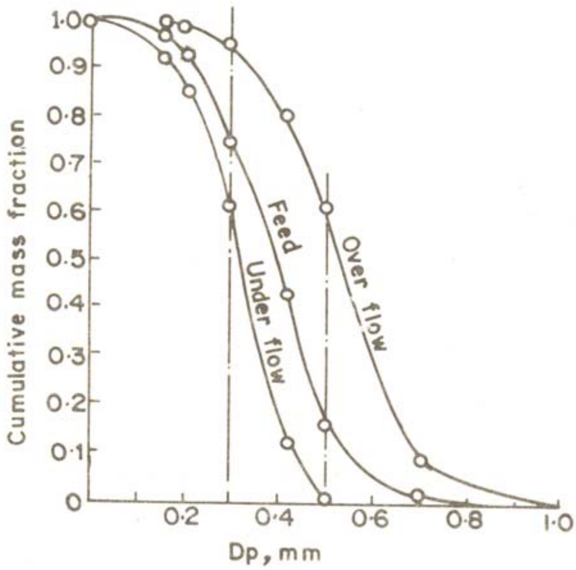

Figure 3.10: Graphical representation of various flows of a screen

In most screens the grain/ seed drops through the screen opening by gravity. Coarse grains drop quickly and easily through large opening in a stationary surface. With finer particles, the screening surface must be agitated in some way. The common ways are, (1) revolving a cylindrical screen about a horizontal axis and (2) shaking, gyrating or vibrating the flat screens.

3.5.1 Grizzly

The grizzly is a simple device consisting of a grid made up of metal bars, usually built on a slope, across which the material is passed. The path of material flow is parallel to the length of bars. The bars are usually so shaped that the top is wider than the bottom. The grizzly is often constructed in the form of a short endless belt so that the oversize is dumped over the end while the sized material passes through. In this case bar length is transverse to the path of materials. The grizzly is used for coarsest and rough separations.

3.5.2 Revolving Screen/Cylinder Sorter

Trommel or revolving screen is a cylinder that rotates about its longitudinal axis. The wall of the cylinder is made of perforated steel plate or sometime the cloth wire on a frame, through which the material falls as the screen rotates. The axis of cylinder is inclined along with the feed end to the discharge end. Sizing is achieved by having smallest opening screen at the feed end with progressively larger opening screens towards the discharge end. This type of sorter is simple and compact with no vibration problem. But the capacity of cylinder sorter is lesser than the vibrating screen of same size. Although it is an accurate sizer, it does not perform well with friable material or in cases where particle degradation is undesirable because tumbling produces some autogeneous grinding. The speed of rotation of the trommel is kept within the limit at which the material is carried from bottom to a distance equal to the radius of cylinder before it starts tumbling. The inclination of cylinder sorter for dry granular materials is kept up to 125 mm/m. Changing the speed of operation and the inclination of cylinder can change the capacity, bed depth and efficiency of these screens. Effective screening area (not the total surface of cylinder) is calculated by multiplying the length of cylinder by $\frac{1}{3}$ of the diameter.

3.5.3 Shaking Screen

Like the vibrating screen, shaker is a rectangular surface over which material moves down on an inclined plane. Motion of the screen is back and forth in a straight line. Although in some cases vibration is also given to the screen. Unlike the vibrating screen, the shaker does not tumble or turn material enroute except that some shaking screens have a step-off between surfaces having different size openings, so that there may be two or three tumbles over the full length of the screen. The shaker is widely used as combined screen and conveyor for many types of bulk material.

3.5.4 Rotary Screen

Rotary and gyratory screens are either circular or rectangular decked. Their motion is almost circular and affects sifting action. These are capable of accurate and complete separation of very fine sizes but their capacity is limited. These screens are further classified into two categories.

Gyratory Screens

This is generally a single decked machine. It has horizontal plane motion, which is circular at feed end and reciprocating at the discharge end. The drive mechanism is at the feed end and is either a V-belt or direct coupling. The shaft that imparts motion to the screen is a counter balanced eccentric. The shaft moves about a vertical axis. At the discharge end most rotary screens have linkage to the base frame, usually a self-aligning bearing. Gyratory screens operate with screening surface nearly horizontal.

Circular Screens

These are also rotary screens but their motion in horizontal plane is circular over the entire surface. Similar to the gyratory screens, the screening surface of circular screens is also little bit tilted for allowing the material to move over them.

3.5.5 Vibratory Screen

The vibratory screens are agitated by an eccentric unit. When materials to be separated are put on a vibratory screen, because of its vibration, materials are also agitated and separated during their transit over the screen. The eccentricity is usually of two types, (1) a shaft to which off centre weights are attached, and (2) a shaft that itself is eccentric or off centred. In the later case the eccentricity is balanced by a fly wheel for providing uniform vibration. Most vibrating screens are inclined downward from the feed end. Vibration is provided to the screen assembly only, and the body and other surrounding structure are isolated from vibration. Generally, upto three decks are used in vibrating screens. The capacity of vibrating screen is higher than any other similar sized screen and is very popular for cleaning and grading of granular agricultural products.

3.5.6 Horizontal Screen

Horizontal screens are special case of vibrating screen. These are designed for operation with low head room. They operate absolutely flat without the aid of gravity. All sorting, stratification and material transportation' take place on the strength of a sharp forward thrust which imparts motion to particles with a missile like trajectory, while the return stroke pulls the deck out from underneath the bed. Effectiveness of these screens is higher because material is kept on the screen for a longer period in comparison to inclined screens.

3.5.7 Other Screens

Various other types of screens used for cleaning and separation are listed below:

1. Rotex screens
2. Hummer screens
3. Circular vibrators
4. Symon's rod deck screens
5. Resonant vibrant screens
6. Centrifugal screens

3.5.8 Particle Motions in Separation Equipment

There are four different regime motions that can take place for the rigid particles placed on a moving trough depending upon the frequency of oscillation. The regimes are given below:

1. Particles stationary with respect to trough.

2. Particles slip during part of cycle and remain adherent to the trough during the rest of cycle.

3. As regime (2) with slip and gliding motion.

4. Particles purely in stick and slip motion.

Reciprocatory Motion

This can be either purely in horizontal plane or in an inclined plane. Depending upon the plane, the motion of particles is different as given below:

a) **Horizontal reciprocating motion:** This motion is obtained with an eccentric and a connecting rod and is usually in a path parallel to the horizontal projection of the path of material as it moves from inlet to outlet as shown in Figure 3.11. If the pitch (amplitude) is steep enough the motion has a substantial vertical component to the screen surface, which initiates sliding motion, and a large quantity of material can be moved.

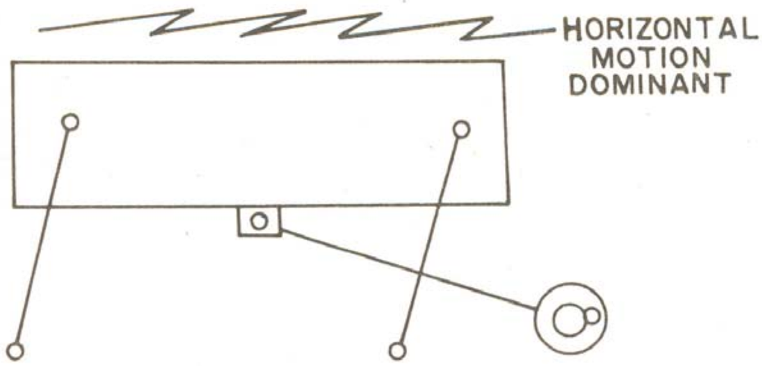

Figure 3.11: Horizontal reciprocating motion

b) **Inclined reciprocating motion:** The screen can be moved in an inclined plane reciprocatingly by eccentric and connecting rod unit (Figure 3.12). Such motion would have a vertical and horizontal components parallel to the horizontal projection of path of moving material. Combined horizontal and vertical motion can also be achieved by a rotary drive attached directly to the screen and operating in a vertical plane parallel to the path of the material flow. The horizontal motion is shown in Fig 3.13b and the vertical motion is shown in Fig 3.13a. The vertical component lifts the material from the screen surface for a fraction of time. The vertical motion can loosen the mass of material thus dislodging finer particles to settle at the bottom. The combined vertical and horizontal motion is also effective in moving large volume of material rapidly over the surface. This technique is useful in coarse sifting or where the screen openings are substantially larger than the particle size.

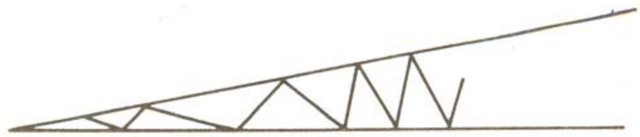

Figure 3.12: Inclined reciprocatory motion

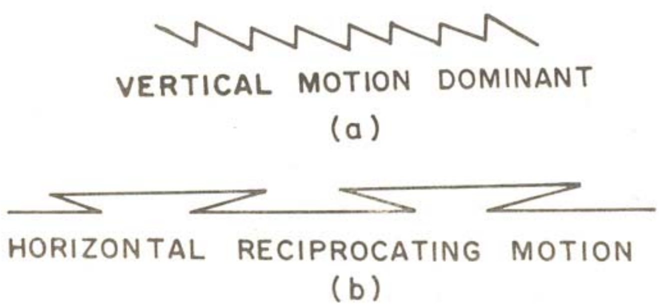

Figure 3.13: a) and b) Vertical and horizontal reciprocating motion

Combined Horizontal and Reciprocating Motion

In this, an eccentric drive is used to change the horizontal reciprocating motion into a rotary motion in a horizontal plane at inlet end, whereas the other end has reciprocating motion. In such arrangement there is a component of reciprocating motion both in parallel and perpendicular to the direction of material flow at inlet and this gradually changes into an elliptical motion at the central section of the screen and finally becomes a true reciprocating motion at the discharge end as shown in Figure 3.14. This section is effective in spreading the material to the sides of screen at the inlet end. The looping path of the material also presents more screen openings since particle moves not only back and forth but also from side to side across the screen surface.

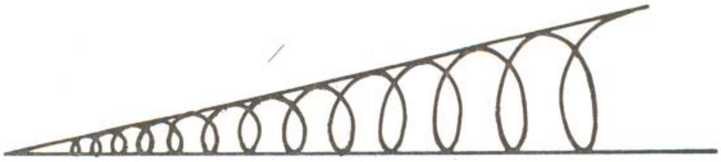

Figure 3.14: Combined horizontal and reciprocating motion

Horizontal Rotary Motion

If the screen surface is rotated in a horizontal plane the material will travel in the overlapping loop path during the passage from inlet to discharge end as shown in Figure 3.15. The multidirectional motion overcomes inter particle friction and maximum number of openings are available, thus screening can be accomplished on a relatively shorter distance. Rotary motion is provided by an off-centred weight attached to the screen through the frame and it is rotated at proper speed in horizontal plane. This imparts desired frequency and motion. The amplitude of movement is controlled by the magnitude and eccentricity of weight as well as the position, which affects its leverage on the screen. Sifters may also be driven by means of one or more directly connected eccentrics. The speed of eccentric and the amount of eccentricity control the frequency and amplitude of motion.

Figure 3.15: Horizontal rotary motion

3.5.9 Perforated Metal Screens

i) **Round openings:** The round openings in a perforated sheet metal screen are measured by the diameter (mm or in.) of the openings. For example, $\frac{1}{18}$ screen has round perforation of $\frac{1}{18}$ in. in diameter or 2 mm.

ii) **Oblong openings:** The oblong or slotted openings in a perforated sheet metal screen are designated by two dimensions; the width and length of the opening. While mentioning oblong openings the dimension of width is listed first then the length as 1.8 x 20 mm. Generally, the direction of the oblong opening is kept in the direction of the grain flow over the screen.

iii) **Triangular openings:** There are two different systems used to measure triangular perforations. The most commonly used system is to mention the length of each side of the triangle in mm, it means, 9 mm triangle has 3 equal sides each 9 mm long. The second system is to mention openings according to the diameter in mm that can be inscribed inside the triangle. This system is identified by the letter Vas 9V, l0V etc.

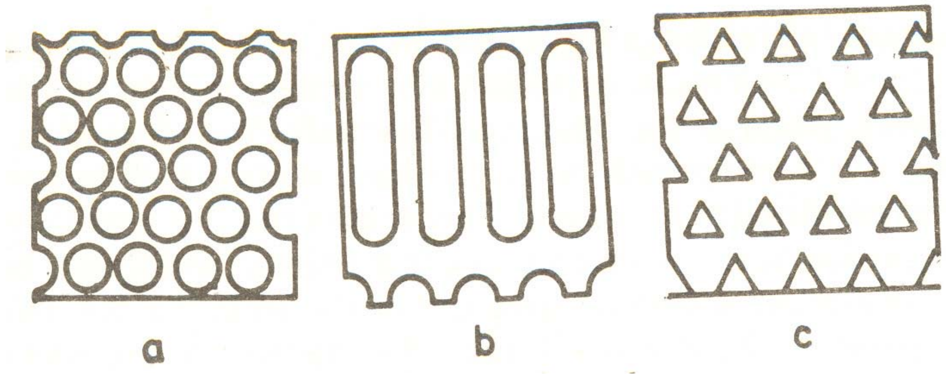

Figure 3.16: Perforated metal screens. a) Round holes, b) Oblong holes, c) Triangular holes

3.5.10 Wiremesh Screens

i) **Square mesh:** The square openings in wire mesh are measured by the number of openings per inch in each direction. A 9×9 screen has 9 openings per inch (Figure 3.17).

ii) **Rectangular mesh:** the rectangular openings in wire mesh screens are measured in the same way as square wire mesh screen. A 3×6 rectangular wire mesh screen will have 3 openings per inch in one direction and 6 openings per inch in the other direction. The rectangles formed by the wire mesh are parallel to the direction of grain flow (Figure 3.18).

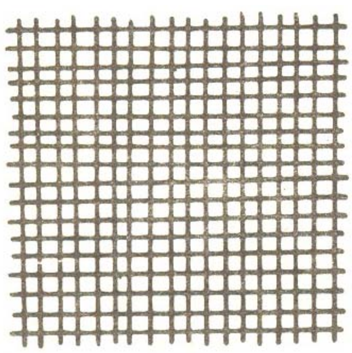

Figure 3.17: Wire mesh screen (square openings)

Figure 3.18: Wire mesh screen (rectangular openings)

3.6 EFFECTIVENESS AND EFFICIENCY OF SCREENS, CLEANERS, GRADERS AND SEPARATORS

The screen effectiveness may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size. If the screen functions properly, all material 'O' would be in the overflow, while all the material 'U' would be in the underflow. The material balance in a screening operation can be derived as follows:

F = mass flow rate of feed, kg/hr.
O = mass flow rate of oversize, kg/hr.
U = mass flow rate of undersize, kg/hr.
m_f = mass fraction of material in feed.
m_o = mass fraction of material in overflow.
m_u = mass fraction of material in underflow.

The total quantity of feed is the sum of overflow and underflow

$$F = O + U$$

or,

$$Fm_f = Om_o + Um_u \tag{3.1}$$

Substituting $O = F - U$ and, $U = F - O$

$$\frac{O}{F} = \frac{m_f - m_u}{m_o - m_u} \tag{3.2}$$

and,
$$\frac{U}{F} = \frac{m_o - m_f}{m_o - m_u} \tag{3.3}$$

A common measure of screen effectiveness is the ratio of actual amount of oversize material in the overflow to the amount of oversize material entering with the feed.

Thus,

$$E_o = \frac{Om_o}{Fm_f} \tag{3.4}$$

and
$$E_u = \frac{U(1 - m_u)}{F(1 - m_f)} \tag{3.5}$$

Overall effectiveness $E = E_o x E_u = \dfrac{OUm_o(1 - m_u)}{F^2 m_f (1 - m_f)}$ (3.6)

Substituting the values of

$$\frac{O}{F} \text{ and } \frac{U}{F}, \; E = \frac{(m_f - m_u)(m_o - m_f)m_o(1 - m_u)}{(m_o - m_u)^2(1 - m_f)m_f} \tag{3.7}$$

The effectiveness of screening or cleaning efficiency for an air screen cleaner as suggested by Bureau of Indian Standards (BIS) is:

$$\text{Cleaning efficiency} = \frac{E(F - G)(E - F)(1 - G)}{F(E - G)^2(1 - F)} \tag{3.8}$$

where, E = fraction of clean seed at clean seed outlet

F = fraction of clean seed in feed

and G = fraction of clean seed at foreign matter outlet

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Enlist four types of screen that are available for cleaning and grading of foods. Describe any one of them.

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2. Define screen effectiveness.

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3. During the evaluation of an air screen grain cleaner with two screens the followings were observed.

   i) The impurities present in feed were 6.5%.
   ii) The impurities present in clean grain were 0.5%.
   iii) The outflow of blower contained 0.2% clean seed.
   iv) The overflow of the 1st screen contained 1 % clean seed.
   v) The underflow contained 0.5% clean seed.

   Compute the cleaning efficiency of the cleaner.

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4. During evaluation of an air screen grain cleaner with 2 screens 250*g* samples were collected for analysis of clean seed fraction from different outlets. The data are presented in the following Table. Calculate the cleaning efficiency of the cleaner.

Sample fraction	Feed, g	Clean grain outlet, g	Blower outlet, g	Oversize outlet, g	Undersize outlet, g
Cleaned seed, g	231.25	246.5	1.25	4.5	2.0
Impurities, g	18.75	3.5	248.75	245.5	248.0

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3.7 LET US SUM UP

In this unit, we have learnt the basics of cleaning and grading operations as specialized forms of the separation process. The methods of cleaning and grading are based upon the properties of the materials. Various machines used for the cleaning and grading operations have been introduced. Screens are used very commonly in the separation processes and, therefore, various types of screens have been presented. The analysis of the screened material ultimately provides the basis of determining the cleaning and separation efficiency.

3.8 KEY WORDS

Cleaning : Generally means the removal of foreign and undesirable material from desired grains / products.

Grading : Refers to the classification of the cleaned product into various quality functions depending upon the commercial value and usage.

Cleaning efficiency : It is the ratio of the actual amount of impurities present in a mixture to the impurities obtained during the cleaning process.

Magnetic separator : Uses the magnetic properties of metallic contaminants to separate them from the produce.

Colour sorting : Uses the colour differences between the produce and the unwanted materials for sorting.

Pneumatic separation : Uses the property of terminal velocity to separate materials.

Screen effectiveness : It may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size.

3.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Cleaning is defined as the method of removal of foreign or undesirable material from the foods whereas grading is defined as the classification of the cleaned produce into various fractions based on qualitative or quantitative parameters.

2. The five characteristics of foods that are used for its separation from unwanted materials include:

   i) Size
   ii) Shape
   iii) Specific gravity or weight
   iv) Surface roughness
   v) Aerodynamic properties

3. i) Air screen separator: Air blast in conjunction with screens is used to achieve the separation. Air blast helps to separate dust and lighter material before the remaining material is separated by screens.

   ii) Inclined draper: The mixture to be separated is fed over the centre of an inclined draper belt moving in upward direction. The round and smooth grains roll or slide down the draper at faster rate than the upward motion of the belt, and these are discharged in a hopper. The flat shape or rough surfaced particles are carried to the top of the inclined draper and dropped off into another hopper. The belts of different degrees of roughness may be used as a draper for separate materials.

   iii) Pneumatic separator: A blower is placed at the inlet of the separator. The mixture is suspended in the air and the different fractions get separated due to their differing terminal velocities.

   iv) Colour sortor: Colour or brightness is sensed by photocells. The photocell gives an output based on the colour/brightness variation and the product is separated if the output is below or above the threshold level.

Check Your Progress Exercise 2

1. Four types of screen that are available for cleaning and grading of foods are:

   a) Horizontal screen
   b) Rotary screen
   c) Grizzly screen
   d) Vibratory screen

Grizzly screen: Grizzly is made up of coarse grid of metal bars usually put on a slope. The path of material flow is parallel to the length of bars. The grizzly is used for rough and coarse separation like crushed stones, ores etc.

2. The screen effectiveness may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size.

3. i) fraction of clean seed in feed = 100 - 6.5 = 93.5 or 0.935

ii) fraction of clean seed in clean grain outlet = 100 - 0.5 = 99.5 or 0.995

iii) fraction of clean seed in foreign matter outlets = $\frac{0.2}{100} + \frac{1}{100} + \frac{0.5}{100}$

$= 0.002 + 0.01 + 0.005$

$= 0.017.$

Then E = 0.0995, F = 0.935 and G = 0.017

$$\text{Therefore, Cleaning efficiency} = \frac{E(F-G)(E-F)(1-G)}{F(E-G)^2(1-F)}$$

$$= \frac{0.995(0.935-0.017)(0.995-0.935)(1-0.017)}{0.935(0.995-0.017)^2(1-0.935)}$$

$= 91.18\%$

4. i) Fraction of clean seed at clean seed out let, $E = \frac{246.5}{250.0} = 0.986$

ii) Fraction of clean seed in feed $F = \frac{231.25}{250.0} = 0.925$

iv) Fraction of clean seed in-foreign matter outlets $G = \frac{1.25}{250.0} + \frac{4.5}{250.0} + \frac{2.0}{250.0} = 0.031$

$$\text{Therefore, Cleaning efficiency} = \frac{E(F-G)(E-F)(1-G)}{F(E-G)^2(1-F)}$$

$$= \frac{0.986(0.925-0.031)(0.986-0.925)(1-0.031)}{0.925(0.986-0.031)^2(1-0.925)}$$

$= 82.34\%$

3.10 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

UNIT 4 STORAGE

Structure

4.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- explain the importance of storage;
- understand the type of damages take place during storage;
- identify the traditional and improved storage system being followed; and
- underline the types of losses take place.

4.1 INTRODUCTION

Horticultural crops not only provide us with nutritional and healthy foods, but also generate a cash income to growers. Appropriate production practices, careful harvesting and proper packaging, storage and transport contribute to the good produce quality. Once a crop is harvested it is impossible to improve its quality. The horticultural crops, because of their high moisture content are inherently more liable to deteriorate especially under tropical conditions. Moreover, they are biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which deteriorate the quality of the produce.

Losses during post harvest operations due to improper storage and handling are enormous and can range from 10-40 percent. Post harvest losses can occur in the field, in packing areas, in storage, during transportation and in the wholesale and retail markets. Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers. Losses can be reduced if proper storage process is adopted after harvesting.

Storage of fresh fruit and vegetable produce is an important economic aspect as it stabilizes prices, avoids glut in the market, and makes fruits and vegetables available in off season. Storage extends the usefulness and availability of vegetables and fruits since deterioration of the freshness is minimized. Storage also avoids wastage, relieves stress during main season and assures regular supply to the consumers with high quality fruits and vegetables. If not stored, the farmers have to sell the produce soon after harvest at throwaway prices in the market and they suffer great loss. Therefore, creation of storage facilities is essential for proper development of vegetable and fruit industries in the country.

4.2 STORAGE PARAMETERS FOR FRESH PRODUCE

Temperature and humidity management remains the most effective tool for extending the shelf life of fresh horticultural produce. The following table gives approximate storage life and recommended temperature and humidity levels for commercial storage.

Commodity	Temp (^{0}C)	Relative humidity (%)	Approximate storage life	Highest freezing point
Apples	-1 to 4	90-95	1-12 months	-1.5
Apricots	-0.5 to 0	90-95	1-3 weeks	-1.0
Bananas, green	13 to 14	90-95	-	-0.7
Blackberries	-0.5 to 0	90-95	2-3 days	-0.7
Blueberries	-0.5 to 0	90-95	2 weeks	-1.2
Cranberries	2 to 4	90-95	2-4 months	-0.8
Currants	-0.5 to 0	90-95	1-4 weeks	-1.0
Dewberries	-0.5 to 0	90-95	2-3 days	-1.2
Elderberries	-0.5 to 0	90-95	1-2 weeks	-
Loganberries	-0.5 to 0	90-95	2-3 days	-1.2
Raspberries	-0.5 to 0	90-95	2-3 days	-1.0
Strawberries	0	90-95	5-7 days	-0.7
Carambola	9 to 10	85-90	3-4 weeks	-
Cherries, sour	0	90-95	3-7 days	-1.7
Cherries, sweet	-1 to -0.5	90-95	2-3 weeks	-1.8
Coconuts	0to 1.5	80-85	1-2 months	-0.9
Dates	-18 or 0	75	6-12 months	-15.7
Figs, fresh	-0.5 to 0	85-90	7-10 days	-2.4
Grapes	-1 to -0.5	90-95	1-6 months	-2.1
Guavas	5 to 10	90	2-3 weeks	-

Kiwifruit	-0.5 to 0	90-95	3-5 months	-1.6
Lemons	7 to 13	85-90	1-6 months	-1.4
Limes	9 to 10	85-90	6-8 weeks	-1.6
Loquats	0	90	3 weeks	-
Lychees	1.5	90-95	3-5 weeks	-
Mangos	13	85-90	2-3 weeks	-0.9
Nectarines	-0.5 to 0	90-95	2-4 weeks	-0.9
Olives, fresh	5 to 10	85-90	4-6 weeks	-1.4
Papayas	7	85-90	1-3 weeks	-0.9
Passion fruit	7-10	85-90	3-5 weeks	-
Peaches	-0.5-0	90-95	2-4 weeks	-0.9
Pears	-1.5 to -0.5	90-95	2-7 months	-1.5
Persimmons, Japanese	-1	90	3-4 months	-2.1
Pineapples	7 to 13	85-90	2-4 weeks	-1.1
Plums and prunes	-0.5 to 0	90-95	2-5 weeks	-0.8
Pomegranates	5	90-95	2-3 months	-3.0
Quinces	-0.5 to 0	90	2-3 months	-2.0
Artichokes, globe	0	95-100	2-3 weeks	-1.1
Beans, dry	4 to 10	40-50	6-10 months	-
Beans, green or snap	4 to 7	95	7-10 days	-0.7
Beans, lima	3 to 5	95	5-7 days	-0.6
Bean sprouts	0	95-100	7-9 days	-
Beets, bunched	0	98-100	10-14 days	-0.4
Beets, topped	0	98-100	4-6 months	-0.9
Broccoli	0	95-100	10-14 days	-0.6
Brussels sprouts	0	95-100	3-5 weeks	-0.8
Cabbage	0	98-100	3-6 weeks	-0.9
Carrots	0	95-100	2 weeks	-
Carrots, mature	0	98-100	7-9 months	-1.4
Cauliflower	0	95-98	3-4 weeks	-0.8
Celery	0	98-100	2-3 months	-0.5
Corn, sweet	0	95-98	5-8 days	-0.6
Cucumbers	10 to 13	95	10-14 days	-0.5
Eggplants	8 to 12	90-95	1 week	-0.8

Garlic	0	65-70	6-7 months	-0.8
Ginger	13	65	6 months	-
Greens, leafy	0	95-100	10-14 days	-
Horseradish	-1.0 to 0	98-100	10-12 months	-1.8
Lettuce	0	98-100	2-3 weeks	-0.2
Watermelons	10 to 15	90	2-3 weeks	-0.4
Mushrooms	0	95	3-4 days	-0.9
Okra	7 to 10	90-95	7-10 days	-1.8
Onion, green	0	95-100	3-4 weeks	-0.9
Onion, dry	0	65-70	1-8 months	-0.8
Onion sets	0	65-70	6-8 months	-0.8
Parsley	0	95-100	2-2.5 months	-1.1
Parsnips	0	98-100	4-6 months	-0.9
Peppers, chilli (dry)	0 to 10	60-70	6 months	-
Peppers, sweet	7 to 13	90-95	2-3 weeks	-0.7
Potatoes	0	90-95	5-10 months	-0.6
Pumpkins	10 to 13	50-70	2-3 months	-0.8
Radishes	0	95-100	3-4 weeks	-0.7
Spinach	0	95-100	10-14 days	-0.3
Sweet potatoes	13 to 16	85-90	4-7 months	-1.3
Tomatoes, mature-green	13 to 21	90-95	1-3 weeks	-0.6
Tomatoes, firm-ripe	8 to 10	90-95	4-7days	-0.5
Turnips	0	95	4-5 months	-1.0
Turnip greens	0	95-100	10-14 days	-0.2

4.3 DAMAGES DURING STORAGE

Insect/ pests form one of the most important factors responsible for losses in agricultural production at various stages. Living organisms and the environment interact to bring about spoilage of stored products. Living organisms may be plants, insects, pests, man, animal, bacteria, fungi etc. High post-harvest losses are caused by the invasion of fungi, bacteria, insects and other organisms. Micro-organisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defence mechanism and has plenty of nutrients and moisture to support microbial growth. Control of Post harvest decay is becoming a more difficult task, because the number of pesticides available is falling rapidly as consumer concern for food safety increases.

It is estimated that 5 to 10% of the world food production is damaged by insects during storage. The estimated losses due to insects in India have been estimated to be around 3% of the country's production. Insects feed on the germ and endosperm causing loss in weight as well as nutrients. Besides, they cause contamination with their excreta and dead bodies. The damages can be grouped into, (1) direct damages, and (2) indirect damages.

4.4 DIRECT DAMAGES

i) Few insects consume germ as well as some endosperm and the others eat away both. It causes in loss of weight, loss of nutrients, loss of germination power, loss in gradation and consequently falls in market value.

ii) The contamination may be with the dead bodies, excreta, cast skin, odour.

iii) Structures and containers also get damaged by causing tunneling in wooden parts.

4.5 INDIRECT DAMAGES

i) It occurs when heat is created and migration of moisture takes place.

ii) It creates distribution of parasites to man. Few tape worms select stored grain insects as intermediate hosts.

4.6 SOURCES OF INFESTATION

Infestation sources are mainly five types, the field itself, infested bags, infested transport, infested godown and infested stocks.

Field: Insects may attack the crop in the field itself and same is brought to the storage centers where it continues attack. The infestation may be visible or invisible. Fumigation should be done immediately to check the growth of insects.

Infested bags: When new bags are used for packing the newly harvested produce, the insects hiding in the seams of the bags may attack the freshly harvested produce. The gunnies should be fumigated prior to packing the freshly harvested produced.

Infested transport: *DDVP* or Malathion should be sprayed on transport used for carrying the newly harvested produce. If the bullock cart or tractor trolley has been used as the transport for carrying infested stocks on the previous occasion, the left over insects may attack the fresh produce.

Infested godowns: The Godowns *should* be thoroughly cleaned and fumigated as insects present in the cracks and crevices of the wall or that hibernate in the structures, may emerge out and attack the produce.

Infested stocks: In case sound produce/stocks are brought to a storage unit godown where infested stocks are in storage, cross infestation may takes place.

4.7 STORAGE REQUIREMENTS

For successful storage the conditions needed is a better product, optimum required temperature, atmospheric humidity, right stage of maturity for the product to be stored, and freedom from diseases and other injury. There is rapid deterioration in injured or diseased products during storage, particularly under conditions favourable for the development of storage rots. The main storage principles are:

Relative Humidity

Transpiration rates (water loss from produce) are determine by the moisture content of the air, which is usually expressed as relative humidity. At high relative humidity, produce maintains saleable weight; appearance, nutritional quality and flavour, while wilting, softening and juiciness are reduced. Leafy vegetables with high surface-to-volume ratios; injured produce and immature fruits and vegetables have higher transpiration rates. High temperatures, low relative humidity and high air velocity increase transpiration rates.

Relative humidity needs to be monitored and controlled in storage. Control can be achieved by a variety of methods:

1. Operating a humidifier in the storage area.
2. Regulating air movement and ventilation in relation to storage room load.
3. Maintaining refrigeration coil temperature within the storage room.
4. Using moisture barriers in the insulation of the storage room or transport vehicle.
5. Wetting the storage room floor.
6. Using crushed ice to pack produce for shipment.
7. Sprinkling leafy vegetables, cool-season root vegetables and immature fruits and vegetables with water.

Temperature

Respiration and metabolic rates are directly related to room temperatures within a given range. The higher the rate of respiration, the faster the produce deteriorates. Lower temperatures reduce respiration rates and the ripening and senescence processes, which prolong the storage life of fruits and vegetables. Low temperatures also slow the growth of pathogenic fungi, which cause spoilage of fruits and vegetables in storage.

Producers should give special care and attention to proper storage conditions for produce with high to extremely high respiration rates, as these crops will deteriorate much more quickly.

It is impossible to make a single recommendation for cool storage of all fruits and vegetables. Climate of the area where the crop originated, the plant part, the season of harvest and crop maturity at harvest are important factors in determining the optimum temperature. A general rule for vegetables is that cool-season crops should be stored at cooler temperatures (0 to 1.7°C) and warm-season crops should be stored at warmer temperatures (7 to 13°C).

Freezing injury

Temperatures that are too low can be just as damaging as those too high. Freezing will occur in all commodities below 0^oC. Whether injury occurs depends on the commodity. Some can be repeatedly frozen and thawed without damage, while others are ruined by one freezing.

Injury from freezing temperatures can appear in plant tissues as loss of rigidity, softening and water soaking. Injury can be reduced if the produce is allowed to warm up slowly to optimum storage temperatures and if it is not handled during the thawing period. Injured produce should be marketed immediately, as freezing shortens its storage life.

Chilling injury

Fruits and vegetables that require warmer storage temperatures (4.5 to 13°C) can be damaged if they are subjected to near-freezing temperatures (0°C). Cooler temperatures interfere with normal metabolic processes. Injury symptoms are varied and often do not develop until the produce has been returned to warmer temperatures for several days. Besides physical damage, chilled produce is often more susceptible to disease infection.

Quality and condition of material

If the fruits are over ripe, they will rot and get spoilt early and quickly. If they are not ripe, the shrinkage can take place and make the product unfit for consumption. The flavour and aroma also changes leading to an appreciable reduction in sugar content and development of acidic (or off-flavour) flavours under storage or transit due to high content of acids. There is also a considerable change in original colour of skin, flesh, firmness, etc, and the product (fruit, root, etc.) becomes soft. The chemical changes continue to take place in immature product (fruits etc) after harvest. The starch content begins to decline and there is increase in sugar content. Also a slow inversion of sucrose to reducing sugars takes place.

Total nitrogen content almost remains the same, but the form of nitrogen is changed, that is, protein and nitrogen decrease compared to soluble nitrogen, fats, oils and waxes increase in storage but oil content increases faster compared to rest. Regarding enzymes the activity of oxidase remains almost constant while catalase activity becomes faster in storage. The mineral constituents also remain constant in the storage. The respiration rate is faster till the fruits are fully mature and finally over mature

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. The old age saying that one bad apple spoils the whole bushel is true. The damaged or diseased fruits produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to disease. Ethylene "producers" should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life and specific symptoms of injury. Ethylene producers include apples, apricots, avocados, ripening bananas, honeydew melons, papayas, peaches, pears, plums and tomatoes.

Advantages of storage

1. The wastage is avoided.
2. The stress during main season is relieved. It is easy to carry over the produce from periods of high production to periods of low production.
3. Distress selling during glut is offset which ensures remunerative price to the grower.
4. It assures regular supply to the consumer of high quality fresh fruit and vegetables throughout the year at reasonable prices.
5. It is easy to supply and hold regular trade of vegetables from the place of production to the place of consumption.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why storage of fruit and vegetables are required?

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2. What are the factors responsible for proper storage of fruits and vegetables?

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3. What are the sources of Infestation in storage?

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4. What are various injury occur to fruit and vegetables during storage?

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4.8 STORAGE PROCESS

Most rapidly maturing tropical fruits, soft fruits of all kinds, and leafy vegetables with a large surface area tend to have high respiration rates and normally have short storage lives. In contrast, most temperate fruits, cured potatoes and onions, and vegetable root crops often have lower respiration rates and consequently longer storage lives. Respiration of all produce increases with temperature, which is why all storage techniques aim for a reduction in temperature of the produce.

- Lower storage temperature offers the additional advantage of greatly reduced water loss from the produce with reduced transpiration. High relative humidity slows down water loss and enhances storage life of the produce. Stores should ideally be maintained at the highest relative humidity (RH) that the crop could tolerate.

It is important to retain adequate circulation of the air within a store and around the produce to ensure efficient cooling. However, over-rapid air movement can drastically increase water loss by the produce. Therefore, the choice of the correct storage technique is governed by:

- the type of produce, its temperature from harvest and its respiration rate as well as produce quality;
- the storage temperature and humidity best suited to the produce and intended storage life, with implicating chill damage or unnecessary microbial spoilage;
- appropriateness to the market place and its requirements;
- and above all, the economics of the whole operation.

The different types of storages are (i) ground or pit storage; (ii) natural caves (iii) air-cooled storage; (iv) evaporative cooling (v) ventilated Storages (vi) improved Zero-energy Cool Chamber (vii) refrigerated storages; (viii) controlled atmosphere (CA), modified atmospheres (MA) or Hypo baric storage.

4.9 TRADITIONAL STORAGE STRUCTURES

Ground storage or pit storage

This method of storing vegetables is very commonly followed to the hills, especially in the snow-bound, arid dry template area, deep in the Himalayas. It is always available, simple, cheap, easily made and effective method practiced in some areas. The vegetables like potato, beetroot, carrot, radish, turnip, sweet potato and cabbage are piled in layers in the pit or trenches dug at a higher, well-drained place where water after snow melting does not accumulate. The pits may be pucca or kuchcha and lined with straw or leaves, the produce is then covered with straw followed by a thin layer of soil or prevents severe freezing injury. However, the trenches/ pits are also covered with wooden planks or tree branches and a small hole is kept for proper aeration at each corner.

Cellers and caves

The cellers are sophisticated type of below ground storage. These can be part of above ground buildings or underground rooms, where access is easy. The caves are also the natural shelters available under big rocks, which are used for storing vegetables. Good drainage, protection from rains or snowfall and natural hazards are essential. The performance of cellers is improved by providing controlled ventilation, openings for entrance of cold air and exit for warm air by conventional circulation whenever cooling is required. Though optimum temperatures generally cannot be retained. A good, cellar/cave will provide satisfactory storage for hard vegetables.

4.10 IMPROVED STORAGE STRUCTURES

Air-cooled storage

These are simply insulated structures, above ground and partly underground, which are cooled by circulation of colder monoxide air. When the temperature of the produce is of desired level and the temperature of the outside air is comparatively lower, air is circulated at the stock in the store mechanically through bottom inlet vents and top dampers. Fans if fitted are controlled manually or automatically. Air-cooled stores are cheap, easy to install and to operate, which are still widely used for the storage of potato and sweet potato, because both these products need relatively higher storage temperatures to avoid accumulation of sugar and chilling injury, respectively. Potatoes are commonly stored in bulk, piled in stores with air delivery even under the floor or at floor level and with sufficiently spaced air outlets.

Evaporative cooling

This utilizes the evaporation of water using heat of respiration of the vegetables. Water should be near or around the vegetables. Hot, dry air is thus cooled when it flows through a wet surface. The temperature may be reduced 1°-5°C and relative humidity increases by 20-30 percent depending on the prevailing temperature and relative humidity. The hotter and drier the surrounding microclimate, the greater the decrease in temperature and higher the increase in relative humidity. Evaporative cooling is very useful, especially in vegetables which easily wilt, shrivel, or soften because of low relative humidity. A few applications of evaporative cooling can be; (i) sprinkling fresh vegetables with water; (ii) keeping fresh vegetables in moist containers (earthen pots or jars); (iii) keeping vegetables inside drip coolers. There are locally developed structures with sides which could absorb water to be evaporated like jute sack or charcoal held on two sides by wire netting. Water is allowed to drip on the walls continuously

Ventilated Storages

Before the advent of refrigeration, ventilated storage was the only means available for storage of fresh produce and today is still in wide use all over the world for a variety of crops. Ventilated storage is ambient air storage, which makes use of controlled ventilation for cooling of the produce and maintenance of lower temperatures. It requires much lower capital investment and operating costs than refrigerated storage and is perfectly adequate for some crops and conditions where:

- Production is being stored for local use.
- The crops to be stored have a relatively long natural and storage life.
- Regular inspection is possible to remove spoilage centers.
- There is a significant difference between day and night temperatures, for example at altitudes above 1000 meters and most temperate latitudes.
- The need is for relatively short storage periods.

A ventilated store may be used for onions, garlic, yams and sweet potato. However, ambient or ventilated storage for most other commodities is neither a practical nor an economic proposition because spoilage rates are simply too high. Some ventilated storage at the retail point may be an every day reality for small shopkeepers but larger ships and supermarkets, and most importers and wholesalers use refrigerated stores. Hanging onions and garlic are the simplest form of ventilated storage. In low temperature areas, storage houses for potatoes have air inlets at the sides near the floor level and outlets near the ceiling. These storage houses are found ventilated. The entry and exit of fresh air is mechanically controlled by thermostats, which also measure temperature inside and outside the room. Air is allowed to enter when it is cold and to leave when it is hot.

Improved Zero-energy Cool Chamber

A low cost zero-energy cool chamber, developed at IARI, New Delhi, recently is based on the principle of evaporating cooling. Raw material readily available is used for installing the short-term double-walled storage for fresh vegetables and fruits. The inside temperature of the chamber maintained is between 17-18°C (lower than outside) with relative humidity of about 90 percent during the peak summer months and also throughout the year. Such chambers are quite suitable for storage of fresh vegetables for short duration. Moreover, these are cheap, economical and within the reach of an average vegetable grower.

4.11 MODERN STORAGE STRUCTURES

Refrigerated Storage

Refrigerated storage is a well-established technology widely used for storing horticultural crops all over the world and is undoubtly the most effective method of prolonging the storage shelf life of fresh vegetables and reduces post-harvest losses by arresting metabolic breakdown of fungal deterioration of the commodity. Its application is limited only by cost and benefit considerations. Essentially, all crops can benefit by being stored at a suitable low temperature, which extends the storage life and preserves quality.

Many horticultural crops have storage life spans ranging from less than one month to several months when refrigerated. Therefore, refrigerated storage can be used continuously only if different crops with different harvesting seasons can share the facility. There are other important reasons why this method is not used in many tropical and sub-tropical countries, where refrigeration is needed most. The initial investment cost is too high and its energy consumption too large for many countries

When this method is to be used on a large-scale, the total value of the commodity should be considered. It may keep the commodity fresh for a long period but if it is not profitable to put in refrigerated store or even to rent a refrigerated room, then it is economical to use other methods of storage. Many tropical and subtropical fruit and vegetables are susceptible to low temperature injury. Due to the lack of money to erect and run cold storages by the individual farmer or farming community, the use of cold storages is limited. However, some well-to-do farmers and government agencies have created these facilities and are making use of them for storing high-priced vegetables. As the commodities have their optimum temperature and relative humidity at which they keep fresh for the longest possible time, therefore the cold room should have the desired temperature and relative humidity

The commodities should be cooled as soon as possible. Root and bulb vegetables should be properly cured before storing for better protection from micro-organisms. For better results, avoid mixing different commodities because most of the fruit & vegetables release ethylene on their ripening, thus leafy vegetables root and bulb vegetables and green fruit vegetables should not be mixed. Only good quality produce should be stored in different chambers. Storing of poor quality produce may not be economical in the long run. The faster the temperature of the vegetable is lowered down to the optimum, the longer is the shelf life of the commodity. Cooling vegetables and fruits immediately after harvesting before storage at the optimum temperature is an effective way to remove both field and product heat leading to slow deterioration. The fast cooling is called pre-cooling and is done by cooling in special pre-cooling chambers or equipment with air (room cooling)- with a much higher capacity to cool than a usual cold room. In lead water (hydro cooler), the vegetable is sprayed or immersed in ice water, here the cooling time is determined by the temperature difference between the water and the vegetable, the nature of the vegetable and type of container used.

4.12 CONTROLLED ATMOSPHERE (CA) AND MODIFIED ATMOSPHERE (MA) OR HYPERBOLIC STORAGE

The fresh horticultural produce consumes oxygen for respiration and releases carbon dioxide and ethylene. The ethylene further enhances ripening. Reducing oxygen and increasing carbon dioxide can increase the shelf life. In CA storage the levels of CO2, O2 and N2 in the storage room are monitored. CA storage combined with refrigeration reduces respiration and delays yellowing and quality changes. However the tolerance of individual varieties of horticultural crops needs to be considered.

Commercial application of CA storage is limited to only a few crops, apples and pears being the most popular ones. It is not used for other crops because the benefit is too slight to cover the cost. The technologies involved are complicated and sophisticated. The cost of building, facilities, and management for CA storage is considerably higher than for refrigerated storage. Therefore it should not be recommended for any crop without a thorough cost and benefit analysis.

While in modified atmosphere (MA), the respiration of the commodity is allowed to reach a desirable low level of O2 and high level of CO2 inside a closed chamber, container, plastic bag or plastic tent and the gases are maintained at those levels. Both the systems are best used with refrigerated storage involving manipulation of CO2, O2 and N2. Other gases such as ethylene, acetylene and propylene are also considered. MA differs from CA only in how precisely the addition of pressures is modified. CA storage is more precise than MA storage without basis or reducing the atmospheric gaseous pressure exerted on the stored valuable vegetables. The CA is seldom used commercially for vegetables, whereas the use of plastic bags to line containers or as retain packages is an example of modified atmosphere. For prevention of accumulation of too much CO2 and decrease of too much O2, a few holes can be made.

Danish cabbage has been reported to be kept better during four to five months at 0˚C in gas mixtures with 2.5 to 5% oxygen and carbon dioxide than it has in air. Mature green tomatoes may keep green for five to six weeks at 13˚C in an atmosphere at 3% oxygen with 97% nitrogen. After removal to air at 18˚ C, these tomatoes ripened normally with acceptable flavour. Mushroom in refrigerated storage has been kept better for short periods in atmosphere with 5 to 10% carbon dioxide than air.

All types of controlled atmosphere storage require frequent gas analysis to determine when aeration is required to add oxygen or to remove carbon dioxide

Therefore, the fresh fruit and vegetables storage can help in bringing lucrative returns to the vegetable growers and others dealing with the vegetable, trade, and supplying fresh, full of flavour, aroma and attractive vegetables from the different areas, in original state to the consumers. Thus, there is great potentiality of storing vegetables and fruits for both fresh and in processed form.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is various storage structure required in traditional storage system?

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2. What is various storage structure required in improved storage system?

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4.13 LOSSES IN STORAGE

Fruits, vegetables, root crops, ornamentals collectively called horticulture products are inherently perishable. Losses occur in the period between harvesting and consumption. The loss is generally a result of multiple causes and malpractices along the marketing chain.

About 20% of the damage to produce takes place during harvesting and field handling. The grower should ensure that the produce is harvested well, is kept in good condition till it is treated, kept in safe storage, consumed or sold.

If post harvest treatments are being used, they should start immediately after the produce has been harvested, to ensure that the essential freshness and nutritional values are maintained to the maximum.

Losses during post harvest operations due to improper storage and handling are enormous and can range from 10-40 percent. Post harvest losses can occur in the field, in packing areas, in storage, during transportation and in the wholesale and retail market. Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers. Proper storage conditions, temperature and humidity are needed to lengthen the storage life and maintain quality once the crop has been cooled to the optimum storage temperature.

4.14 INDIAN STANDARDS

Various Indian standard are notified by Bureau of Indian Standards, New Delhi, these are given below.

Indian Standards on Storage and Marketing Structures for Agricultural Commodities

IS:

600-1955	Code of practice for construction of BUKHARI type rural food grain storage structure.
601-1955	Code of practice for construction of KOTHARI type food grain storage structure.

602-1955	Code of practice for construction for MORAI type rural food grain storage structure.
603-1960	Code of practice for construction of underground rural food grain storage structure.
607-1965	Code of practice for construction of bagged food grain storage structures suitable for trade and government purposes (revised).
609-1955	Code of practice for improvement of existing structures used oriented to be used for food grain storage.
631-1961	Aluminium food grain storage bins.
1497-1959	Layout for regulated market yards for agricultural commodities.
1787-1961	Layout for regulated market yards for fruits and vegetables.
1788-1961	Layout for regulated market yards for cattle.
2059-1962	Layout for regulated market yards for tobacco.
2821-1964	Thermo-sampler.
3453-1966	Code of practice for construction of hexagonal type concrete-cum-masonary bins for bulk storage of food grains.
5503(PartI)-1969	General requirements for silos for grain storage: Part I Constructional requirements.
5503(PartII)-1969	General requirements for silos for grain storage: Part II Grain handling equipment and accessories.
5606-1970	Steel bins for grain storage.
5826-1970	Constructional requirements for flat storage structures for grain (capacity above 200 tonnes).
6151 (Part I)-1971	Storage management code: Part I Terminology.
6151 (Part II)-1971	Storage management code: Part II General care in handling and storage of agricultural produce and inputs (superseding IS: 610-1955 and IS: 611-1955).
6201-1971	Constructional requirements for flat storage structures for grains (100-200 tonnes capacity).
6663-1972	Method for determination of angle of repose of grains.

Indian Standards on Storage Structures and Storage Management

IS:

607-1971	Code of practice for construction of bagged storage structures (second revision).

3453-1966	Code of practice for construction of hexagonal type concrete-cum-masonry bins bulk storage of food grains.
3503(Part I)-1969	General requirements for silos for grain storage: Part I Constructional requirements.
3503 (Part II)-1969	General requirements for silos for grain storage: Part II Grain handling equipment and accessories.
5606-1970	Steel bins for grain storage.
5826-1970	Constructional requirements for flat storage structures for grain (capacity above 200 tonnes).
6151 (Part I)-1971	Storage management code: Part I Terminology.
6151 (Part II)-1971	Storage management code: Part II General care in handling and storage of agricultural produce and inputs.
6151 (Part III)-1976	Storage management code: Part III Specific care in handling and storage of agriculture produce and inputs.
6201-1971	Constructional requirements for flat storage structures for grains (100 to 200 tonnes capacity).
6883-1972	Method for determination of angle of repose of grains.
7147 (Part I)-1973	Steel bins for domestic storage: Part I GHARELU KOTHI.
7247	Code of practice for fumigation of agricultural produce
7247 (Part I)-1973	Methyl bromide.
7247 (Part II)-1973	Ethylene dibromide.
7247 (Part III)-1973	Aluminium phosphate.
7247 (Part IV)-1975	Ethylene dichloride and carbon tetrachloride mixture.
7715-1975	Methods for testing suitability of bins for safe storage of food grains.
7716-1975	Method for testing efficacy of fumigation for disinfestations of grains in domestic bins.
8455-1977	Code of practice for construction of polyethylene embedded bins for bulk storage of food grains.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are reason for post harvest losses of fruit and vegetables?

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2. What percentage of losses takes places during storage?

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4.15 LET US SUM UP

Storage of fresh fruits and vegetables produced is an important economic aspect as it tends to stabilize prices to make use of higher production period to low production period, to avoid glut in the market, to make fruits and vegetables available in off season to earn better return. Due to improper storage, infestation takes place in the produce. Proper storage conditions should be maintained during storage. Various parameters such as relative humidity, temperature, etc. are important during storage. Storage can be made in various types of storage structures depending upon capacity and resources available. Important storage methods are Ground storage or pit storage, evaporating cooling, Ventilatated storage, Refrigerated storage, controlled and modified storage.

4.16 KEY WORDS

Temperature : It is the temperature of surroundings of fruits and vegetables stored.

Infestation : It refers to attack of insects and pests on stored product.

Refrigerated storage : In this condition storage temperature ranges from –1C to 10 C. Storage below –1 C is termed as freezer storage.

Airtight storage : Airtight storage refers to storage conditions in which air is minimum (.2% by volume) leading to arrest the insect infestation in dry grains.

4.17 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Need for storage,
   - Storage conditions for optimum condition,
   - Suitable storage condition for various fruit and vegetables.

2. Your answer should include the following points:

   - various factors,
   - relative humidity,
   - temperature,
   - moisture content.

3. Your answer should include the following points:

   Various types of infestation takes places in storage, it include direct damages and indirect damages, all type of sources for infestation should be noted.

4. Your answer should include the following points:

   Various types of injury like freezing and chilling injury should be mentioned

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Ground storage or pit storage,
   - Cellers and caves.

2. Your answer should include the following points:

   - Air-cooled storage,
   - Evaporating cooling,
   - Ventilated storage,
   - Improved Zero-energy cool chamber.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   Reasons for post harvest losses and factor effecting losses.

2. Your answer should include the following points:

   Percentage of losses taken place during post harvest operations.

4.18 SOME USEFUL BOOKS

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3. Arya, Prem Singh (1997) Vegetable Growing In India, MP Publication Pvt. Ltd.

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6. Hardenburg, R.E., Watada, A.E. and Wang, C.Y. (1986) ***The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks.*** U.S. Dept. of Agriculture, Agricultural Handbook No. 66. pp. 130.

7. Kader, A.A. (ed.) (1992) ***Postharvest Technology of Horticultural Crops.*** University of California, Division of Agriculture and Natural Resources. Oakland, California, USA, pp. 296.

8. Janet Bachmann and Richard Earles, NCAT Agriculture Specialists August 2000 ***Postharvest Handling of Fruit & Vegetables*** By ATTRA Ozark Mountains at the University of Arkansas in Fayetteville at P.O. Box 3657, Fayetteville, AR 72702.

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UNIT 5 SIZE REDUCTION

Structure

5.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the principles and methods of size reduction;
- describe various size reduction equipments and their efficiencies; and
- understand the importance of size reduction and able to decide the suitability of different machinery for various uses.

5.1 INTRODUCTION

The term *size reduction* is applied to all the ways in which particles of solids are cut or broken into smaller pieces. Throughout the process industries solids are reduced in size and shape by different methods for different purposes. Reduction in size is brought about by mechanical means without any change in chemical properties of the materials. During size reduction operation, chunks of large particles are crushed or reduced to workable size. In this process uniformity in size and shape of the individual particles of the resultant product is desirable, but difficult to attain. Size reduction sometimes leads to increased reactivity of solids, helps separation of unwanted ingredients and reduces the bulk of fibrous materials for easier handling.

5.2 PRINCIPLES OF SIZE REDUCTION

Crushers and grinders are the equipment mostly used for size reduction of agricultural products. An ideal size reducer should fulfil the following conditions, namely (1) large capacity, (2) should yield a pre-desired sized product or range of size, (3) small power input requirement per unit of product handled and (4) easy and trouble free operation. Usually the performance of any milling equipment is compared with respect to an ideal operation as standard. The characteristics of the actual equipment are compared with those of the ideal unit.

Size reduction results in the production of small particles which may be required either for larger surface area or because of their definite shape, size and number. Amount of power required to create smaller particles is one of the parameters of the efficiency of operation. Second parameter is the desired uniformity of size. The actual unit seldom yields a uniform sized product. Irrespective of uniformity of feed size the ground product consists of a mixture of various particle sizes. In some equipment there is a provision to control the magnitude of the largest particles like the hammer mill, but the fine size is beyond control. In some size reducing machine fines are minimized but they can not be eliminated altogether.

5.3 METHODS OF SIZE REDUCTION

Solids may be broken in many different ways, but only four of them are commonly used in size-reduction machines: (1) compression, (2) impact, (3) attrition or rubbing, and (4) cutting. A nutcracker, a hammer, a file, and a pair of scissors exemplify these four types of action. Sometimes size reduction results from the attrition of a particle by one or more other particles or from intense shear in the supporting fluid. In general, compression is used for coarse reduction of hard solids, to give relatively few fines; impact gives coarse, medium, or fine products; attrition yields very fine products from soft, nonabrasive materials. Cutting gives a definite particle size and sometimes a definite shape, with few or no fines.

Crushing: When an external force is applied on a material in excess of its strength, the material fails because of its rupture in many directions. The particles produced after crushing are irregular in shape and size. The type of material and method of force application affects the characteristics of new surfaces and particles. Food grain flour, grits and meal, ground feed for livestock are made by crushing process. Crushing is also used to extract oil from oilseeds and juice from sugarcane.

Impact: When a material is subjected to sudden blow of force in excess of its strength, it fails, like cracking of nut with the help of a hammer. Operation of hammer mill is an example of dynamic force application by impact method.

Shearing: It is a process of size reduction which combines cutting and crushing. The shearing units consist of a knife and a bar. If the edge of knife or shearing edge is thin enough and sharp, the size reduction process nears to that of cutting, whereas a thick and dull shearing edge performs like a crusher. In a good shearing unit the knife is usually thick enough to overcome the shock resulting from material hitting. In an ideal shearing unit the clearance between the bar and the knife should be as small as practicable and the knife as sharp and thin as possible.

Cutting: In this method, size reduction is accomplished by forcing a sharp and thin knife through the material. In the process minimum deformation and rupture of the material results and the new surface created is more or less undamaged. An ideal cutting device is a knife of excellent sharpness and it should be as thin as practicable. The size of vegetables and fruits are reduced by cutting.

5.4 SIZE REDUCTION EQUIPMENT

Size-reduction equipment is divided into crushers, grinders, ultrafine grinders, and cutting machines. *Crushers* do the heavy work of breaking large pieces of solid material into small lumps. A primary crusher operates on run-of-mine material, accepting anything that comes from the mine face and breaking it into 150 to 250 mm lumps. A secondary crusher reduces these lumps to particles perhaps 6 mm in size. *Grinders* reduce crushed feed to powder. The product from an intermediate grinder might pass a 4O mesh screen; most of the product from a fine grinder would pass a 200 mesh screen with a *74 μm* opening. An *ultrafine grinder* accepts feed particles no larger than 6 mm; the product size is typically 1 to 50 μm. *Cutters* give particles of definite size and shape, 2 to 10 mm in length.

The principal types of size-reduction machines are as follows:

A. Crushers (coarse and fine)

   1. Jaw crushers
   2. Gyratory crushers
   3. Crushing rolls

B. Grinders (intermediate and fine)

   1. Hammer mills; impactors
   2. Rolling-compression mills
      a) Bowl mills
      b) Roller mills
   3. Attrition mills
   4. Tumbling mills
      a) Rod mills
      b) Ball mills; pebble mills
      c) Tube mills; compartment mills

C. Ultrafine grinders

   1. Hammer mills with internal classification
   2. Fluid-energy mills
   3. Agitated mills
   4. Colloidal mills

D. Cutting machines

   1. Knife cutters; dicers; slitters

These machines do their work in distinctly different ways. Compression is the characteristic action of crushers. Grinders employ impact and attrition, sometimes combined with compression; ultrafine grinders operate principally by attrition. A cutting action is of course characteristic of cutters, dicers, and slitters.

5.4.1 Crushers

Crushers are slow-speed machines for coarse reduction of large quantities of solids. The main types are jaw crushers, gyratory crushers, smooth-roll crushers, and toothed-roll crushers. The first three operate by compression and can break large lumps of very hard materials, as in the primary and secondary reduction. Toothed-roll crushers tear the feed apart as well as crushing it; they handle softer feeds like coal, bone, and soft shale.

Jaw crushers: In a jaw crusher feed is admitted between two jaws, set to form a V open at the top. One jaw, the fixed, or anvil, jaw, is nearly vertical and does not move; the other, the swinging jaw, reciprocates in a horizontal plane. It makes an angle of 20° to 30° with the anvil jaw. An eccentric drives it so that it applies great compressive force to lumps caught between the jaws. The jaw faces are flat or slightly bulged; they may carry shallow horizontal grooves. Large lumps caught between the upper parts of the jaws are broken, drop into the narrower space below, and are recrushed the next time the jaws close. After sufficient reduction they drop out the bottom of the machine. The jaws open and close 250 to 400 times per minute.

The most common type of jaw crusher is illustrated in Figure 5.1. In this machine an eccentric drives a pitman connected to two toggle plates, one of which is pinned to the frame and the other to the swinging jaw. The pivot point is at the top of the movable jaw or above the top of the jaws on the centerline of the jaw opening. The greatest amount of motion is at the bottom of the V, which means that there is little tendency for a crusher of this kind to choke. Some machines with a 1.8 by 2 m feed opening can accept rocks 1.8 m in diameter and crush 1200 ton/h to a maximum product size of 250 mm. Smaller secondary crushers reduce the particle size of precrushed feed to 6 to 50 mm at much lower rates of throughput.

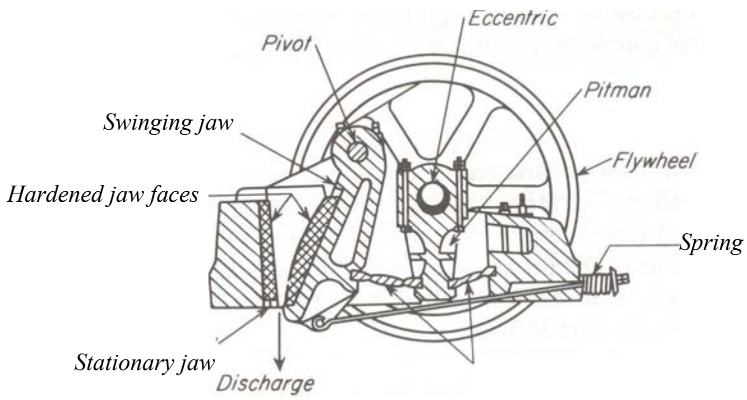

Figure 5.1: Jaw crusher

Gyratory crushers: A gyratory crusher may be looked upon as a jaw crusher with circular jaws, between which material is being crushed at some point at all times. A conical crushing head gyrates inside a funnel-shaped casing, open at the top. As shown in Figure 5.2, the crushing head is carried on a heavy shaft pivoted at the top of the machine. An eccentric drives the bottom end of the shaft. At any point on the periphery of the casing, therefore, the bottom of the crushing head moves toward, and then away from, the stationary wall. Solids caught in the V-shaped space between the head and the casing are broken and rebroken until they pass out the bottom. The crushing head is free to rotate on the shaft and turns slowly because of friction with the material being crushed.

The speed of the crushing head is typically 125 to 425 gyrations per minute. Because some part of the crushing head is working at all times, the discharge from a gyratory is continuous instead of intermittent as in a jaw crusher. The load on the motor is nearly uniform; less maintenance is required than with a jaw crusher; and the power requirement per ton of material crushed is smaller. The biggest gyratories handle up to 4500 ton/h. The capacity of a gyratory crusher varies with the jaw setting, the impact strength of the feed, and the speed of gyration of the machine. The capacity is almost independent of the compressive strength of the material being crushed.

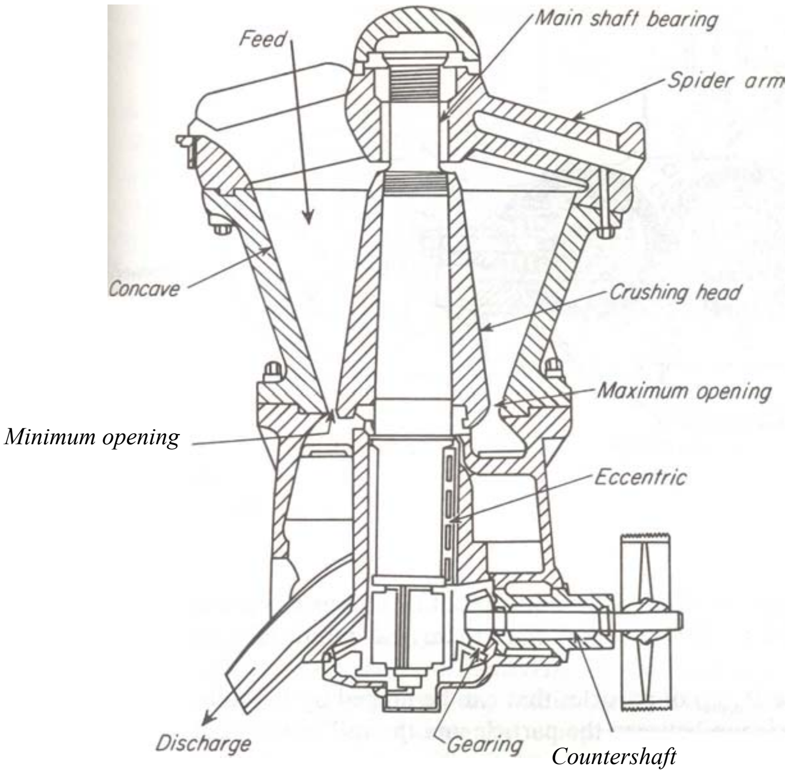

Figure 5.2: Gyratory crusher

Smooth-roll crushers: Two heavy smooth-faced metal rolls turning on parallel horizontal axes are the working elements of the smooth-roll crusher illustrated in Figure 5.3. Particles of feed caught between the rolls are broken in compression and drop out below. The rolls turn toward each other at the same speed. They have relatively narrow faces and are large in diameter so that they can "nip" moderately large lumps. Typical rolls are 600 mm in diameter with a 3OO mm face to 2000 mm in diameter with a 914 mm face. Roll speeds range from 50 to 300 r/min.

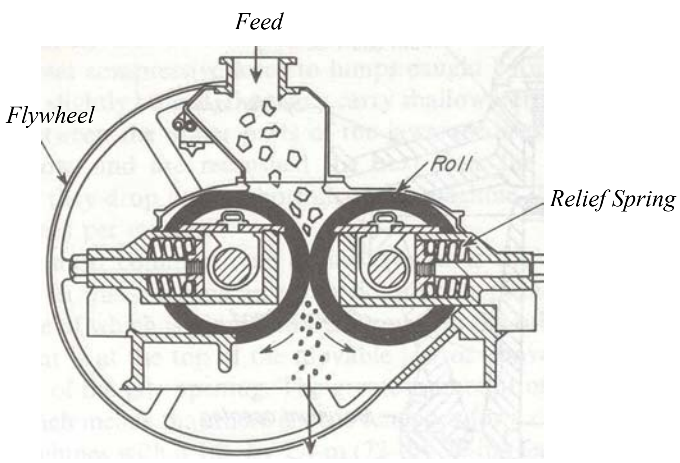

Figure 5.3: Smooth roll crusher

Smooth-roll crushers are secondary crushers, with feeds 12 to 75 mm in size and products 12 mm to about 1 mm. The limiting size $D_{p.max.}$ of particles that can be nipped by the rolls depends on the coefficient of friction between the particle and the roll surface, but in most cases it can be estimated from the simple relation.

$$D_{p.max.} = 0.04R + d5.1 \qquad (5.1)$$

where R = roll radius
d = half the width of the gap between the rolls.

The maximum size of the product is approximately equal to *2d.*

The particle size of the product depends on the spacing between the rolls, as does the capacity of a given machine. Smooth-roll crushers give few fines and virtually no oversize. They operate most effectively when set to give a reduction ratio of 3 or 4 to 1; that is, the maximum particle diameter of the product is one-third or one-fourth that of the feed. The forces exerted by the roll are very great, from 8700 to 70,000 N/cm of roll width. To allow unbreakable material to pass through without damaging the machine, at least one roll must be spring mounted.

Toothed-roll crushers: In many roll crushers the roll faces carry corrugations, breaker bars, or teeth. Such crushers may contain two rolls, as in smooth-roll crushers, or only one roll working against a stationary curved breaker plate. A single-roll toothed crusher is shown in Figure 5.4 Machines known as *disintegrators* contain two corrugated rolls turning at different speeds, which tear the feed apart, or a small high-speed roll with transverse breaker bars on its face turning toward a large slow-speed smooth roll. Some crushing rolls for coarse feeds carry heavy pyramidal teeth.

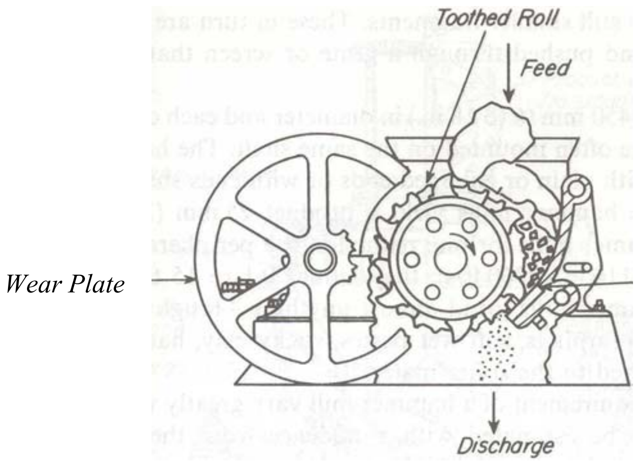

Figure 5.4: Single-roll tooth crusher

Other designs utilize a large number of thin-toothed disks that saw through slabs or sheets of material Toothed-roll crushers are much more versatile than smooth-roll crushers, within the limitation that they cannot handle very hard solids. They operate by compression, impact, and shear, not by compression alone, as do smooth-roll machines. They are not limited by the problem of nip inherent with smooth rolls and can therefore reduce much larger particles. Some heavy-duty toothed double-roll crushers are used for the primary reduction of coal and similar materials. The particle size of the feed to these machines may be as great as 500 mm; their capacity ranges up to 500 tons/h.

5.4.2 Grinders

The term *grinder* describes a variety of size-reduction machines for intermediate duty. The product from a crusher is often fed to a grinder, in which it is reduced to powder. The chief types of commercial grinders described in this section are hammer mills and impactors, rolling-compression machines, attrition mills, and tumbling mills.

Hammer mills and impactors: These mills all contain a high-speed rotor turning inside a cylindrical casing. The shaft is usually horizontal Feed dropped into the top of the casing is broken and falls out through a bottom opening. In a hammer mill the particles are broken by sets of swing hammers pinned to a rotor disk. A particle of feed entering the grinding zone cannot escape being struck by the hammers. It shatters into pieces, which fly against a stationary anvil plate inside the casing and break into still smaller fragments. These in turn are rubbed into powder by the hammers and pushed through a grate or screen that covers the discharge opening.

Several rotor disks, 150 to 450 mm in diameter and each carrying four to eight swing hammers, are often mounted on the same shaft. The hammers may be straight bars of metal with plain or enlarged ends or with ends sharpened to a cutting edge. Intermediate hammer mills yield a product 25 mm to 20-mesh in particle size. In hammer mills for fine reduction the peripheral speed of the hammer tips may reach 110 m/s; they reduce 0.1 to 15 ton/h to sizes finer than 200-mesh. Hammer mills grind almost anything tough fibrous solids like bark or leather, steel turnings, soft wet pastes, sticky clay, hard rock. For fine reduction they are limited to the softer materials.

The capacity and power requirement of a hammer mill vary greatly with the nature of the feed and cannot be estimated with confidence from theoretical considerations. They are best found from published information or better from small-scale or full-scale tests of the mill with a sample of the actual material to be ground. Commercial mills typically reduce 60 to 240 kg of solid per kilowatt hour of energy consumed.

An *impactor,* illustrated in Figure 5.5, resembles a heavy-duty hammer mill except that it contains no grate or screen. Particles are broken by impact alone, without the rubbing action characteristic of a hammer mill. Impactors are often primary-reduction machines, processing up to 600 ton/h. They give particles that are more nearly equidimensional (more "cubical") than the slab-shaped particles from a jaw crusher or gyratory crusher. The rotor in an impactor, as in many hammer mills, may be run in either direction to prolong the life of the hammers.

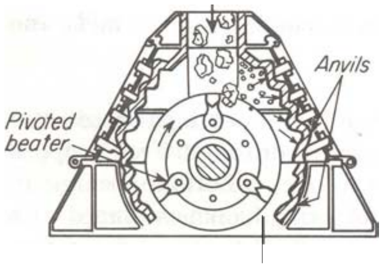

Figure 5.5: Impactor

Rolling-compression machines: In this kind of mill the solid particles are caught and crushed between a rolling member and the face of a ring or casing. The most common types are rolling-ring pulverizers, bowl mills, and roller mills. In the roller mill illustrated in Figure 5.6, vertical cylindrical rollers press outward with great force against a stationary anvil ring or bullring. They are driven at moderate speeds in a circular path. Plows lift the solid lumps from the floor of the mill and direct them between the ring and the rolls, where the reduction takes place. Product is swept out of the mill by a stream of air to a classifier separator, from which oversize particles are returned to the mill for further reduction. In a bowl mill and some roller mills the bowl or ring is driven; the rollers rotate on stationary axes, which may be vertical or horizontal. They pulverize up to 50 ton/h. When classification is used, the product may be as fine as 99 percent through a 200-mesh screen.

Attrition mills: In an attrition mill particles of soft solids are rubbed between the grooved flat faces of rotating circular disks. The axis of the disks is usually horizontal, sometimes vertical. In a single-runner mill one disk is stationary and one rotates; in a double-runner machine both disks are driven at high speed in opposite directions. Feed enters through an opening in the hub of one of the disks; it passes outward through the narrow gap between, the disks and discharges from the periphery into a stationary casing. The width of the gap, within limits, is adjustable. At least one grinding plate is spring mounted so that the disks can separate if unbreakable material gets into the mill. Mills with different patterns of grooves, corrugations, or teeth on the disks perform a variety of operations, including grinding, cracking, granulating, and shredding, and even some operations not related to size reduction at all, such as blending.

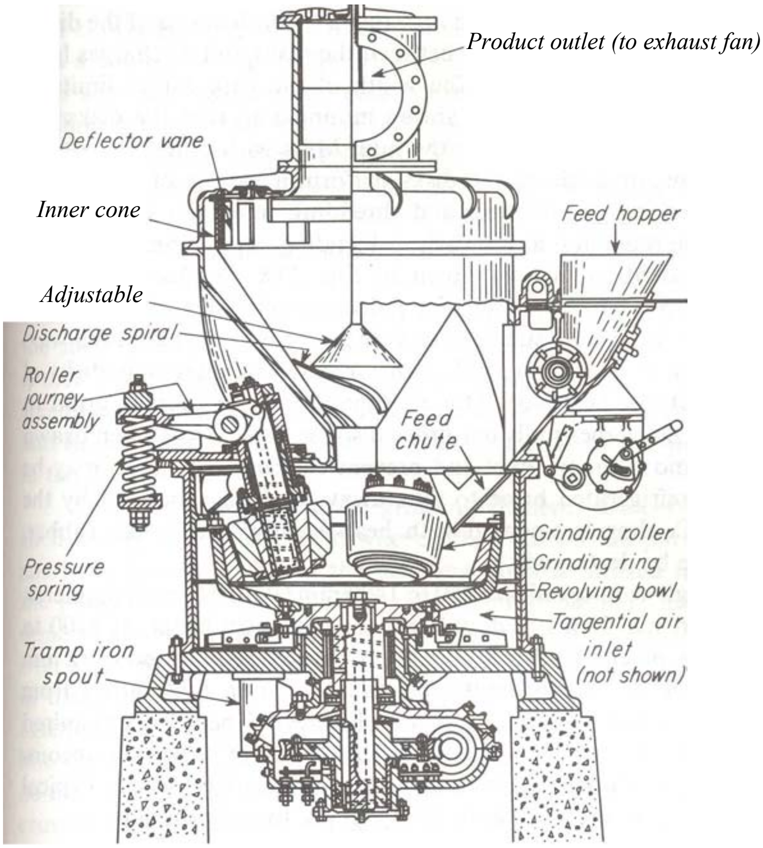

Figure 5.6: Roller mill

A single-runner attrition mill is shown in Figure 5.7. Single-runner mills contain disks of buhrstone or rock emery for reducing solids like spices, starch, insecticide powders, and carnauba wax. Metal disks are usually of white iron, although for corrosive materials disks of stainless steel are sometimes necessary. Double-runner mills, in general, grind to finer products than single-runner mills but process softer feeds. Air is often drawn through the mill to remove the product and prevent choking. The disks may be cooled with water or refrigerated brine to take away the heat generated by the reduction operation. Cooling is essential with heat-sensitive solids like spices, rubber which would otherwise be destroyed.

The disks of a single-runner mill are 250 to 1400 mm in diameter; turning at 350 to 700 r/min. Disks in double-runner mills turn faster, at 1200 to 7000 r/min. The feed is precrushed to a maximum particle size of about 12 mm and must enter at a uniform controlled rate. Attrition mills grind from 1 to 8 ton/h to products that will pass a 200-mesh screen. The energy required depends strongly on the nature of the feed and the degree of reduction accomplished and is much higher than in the mills and crushers described so far. Typical values are between 8 and 80 kWh (10 and 100 hp-h) per ton of product.

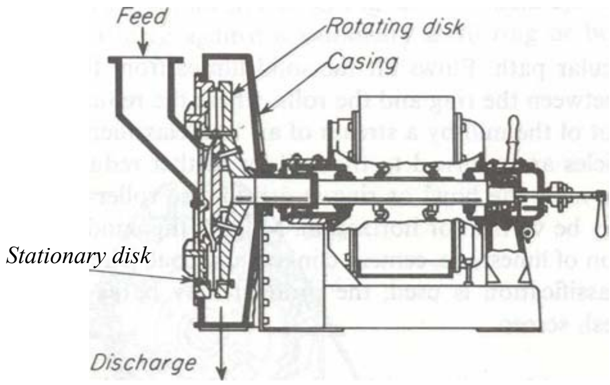

Figure 5.7: Attrition mill

Tumbling mills: A typical tumbling mill is shown in Figure 5.8. A cylindrical shell slowly turning about a horizontal axis and filled to about half its volume with a solid grinding medium forms a tumbling mill. The shell is usually steel, lined with high-carbon steel plate, porcelain, silica rock, or rubber. The grinding medium is metal rods in a rod mill, lengths of chain or balls of metal, rubber, or wood in a ball mill, flint pebbles or porcelain or zircon spheres in a pebble mill. For intermediate and fine reduction of abrasive materials tumbling mills are unequaled.

Unlike the mills previously discussed, all of which require continuous feed, tumbling mills may be continuous or batch. In a batch machine a measured quantity of the solid to be ground is loaded into the mill through an opening in the shell. The opening is then closed and the mill turned on for several hours; it is then stopped and the product is discharged. In a continuous mill the solid flows steadily through the revolving shell, entering at one end through a hollow trunnion and leaving at the other end through the trunnion or through peripheral openings in the shell.

In all tumbling mills, the grinding elements are carried up the side of the shell nearly to the top, from whence they fall on the particles underneath. The energy expended in lifting the grinding units is utilized in reducing the size of the particles. In some tumbling mills, as in a *rod mill,* much of the reduction is done by rolling compression and by attrition as the rods slide downward and roll over one another. The grinding rods are usually steel, 25 to 125 mm in diameter, with several sizes present at all times in any given mill. The rods extend the full length of the mill. They are sometimes kept from twisting out of line by conical ends on the shell. Rod mills are intermediate grinders, reducing a 20 mm feed to perhaps l0 mesh, often preparing the product from a crusher for final reduction in a ball mill. They yield a product with little oversize and a minimum of fines.

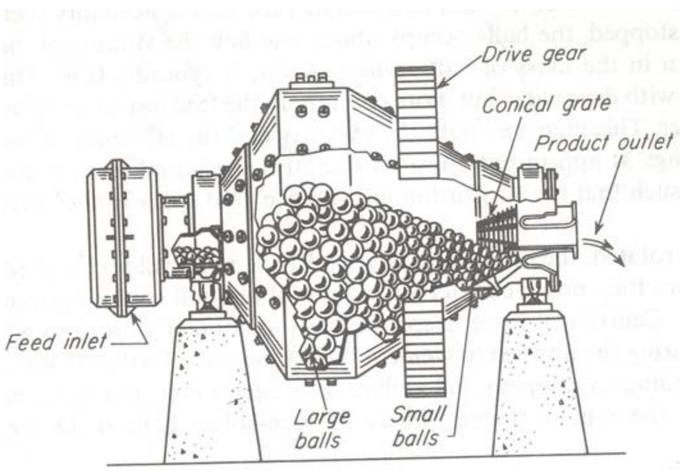

Figure 5.8: Conical ball mill

In a *ball mill* or *pebble mill* most of the reduction is done by impact as the balls or pebbles drop from near the top of the shell. In a large ball mill the shell might be 3 m in diameter and 4.25 m long. The balls are 25 to 125 mm in diameter; the pebbles in a pebble mill are 50 to 175 mm in size. A *tube mill* is a continuous mill with a long cylindrical shell, in which material is ground for 2 to 5 times as long as in the shorter ball mill. Tube mills are excellent for grinding to very fine powders in a single pass where the amount of energy consumed is not of primary importance. Putting slotted transverse partitions in a tube mill converts it into a *compartment mill.* One compartment may contain large balls, another small balls, and a third pebbles. This segregation of the grinding media into elements of different size and weight aids considerably in avoiding wasted work, for the large, heavy balls break only the large particles, without interference by the fines. The small, light balls fall only on small particles, not on large lumps they cannot break.

Segregation of the grinding units in a single chamber is a characteristic of the *conical ball mill* illustrated in Figure 5.8. Feed enters from the left through a 60° cone into the primary grinding zone, where the diameter of the shell is a maximum. Product leaves through the 30° cone to the right. A mill of this kind contains balls of different sizes, all of which wear and become smaller as the mill is operated. New large balls are added periodically. As the shell of such a mill rotates, the large balls move toward the point of maximum diameter, and the small balls migrate toward the discharge. The initial breaking of the feed particles, therefore, is done by the largest balls dropping the greatest distance; small particles are ground by small balls dropping a much smaller distance. The amount of energy expended is suited to the difficulty of the breaking operation, increasing the efficiency of the mill.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Enlist the different characteristics of an ideal size reducing machine.

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2. Describe various methods of size reduction with suitable examples.

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3. Classify the size reduction machines according to the methods used.

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4. Write short notes on the following:

   i) Jaw crusher
   ii) Toothed roll crusher
   iii) Hammer mill
   iv) Attrition mill
   v) Tumbling mill

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5.4.3 Ultrafine Grinders

Many commercial powders must contain particles averaging 1 to 20 μm in size, with substantially all particles passing a standard 325-mesh screen that has openings 44 μm wide. Mills that reduce solids to such fine particles are called *ultra fine grinders*. Ultrafine grinding of dry powder is done by grinders, such as high-speed hammer mills, provided with internal or external classification, and by fluid-energy or jet mills. Ultrafine wet grinding is done in agitated mills.

Classifying hammer mills: A set of swing hammers is held between two rotor disks, much as in a conventional hammer mill. In addition to the hammers the rotor shaft carries two fans, which draw air through the mill in the direction shown in the figure and discharge into ducts leading to collectors for the product. On the rotor disks are short radial vanes for separating oversize particles from those of acceptable size. In the grinding chamber the particles of solid are given a high rotational velocity. Coarse particles are concentrated along the wall of the chamber because of centrifugal force acting on them. The air stream carries finer particles inward from the grinding zone toward the shaft in the direction *AB*. The separator vanes tend to throw particles outward in the direction *BA*. Whether or not a given particle passes between the separator vanes and out to the discharge depends on which force predominates- the drag exerted by the air or the centrifugal force exerted by the vanes. Acceptably fine particles are carried through; particles that are too large are thrown back for further reduction in the grinding chamber. Changing the rotor speed or the size and number of the separator vanes varies the maximum particle size of the product. Mills of this kind reduce 1 or 2 ton/h to an average particle size of 1 to 20 μm, with an energy requirement of about 40 kWh/metric ton.

Fluid energy mills: In these mills the particles are suspended in a high - velocity gas stream. In some designs the gas flows in a circular or elliptical path; in others there are jets that oppose one another or vigorously agitate a fluidized bed. Some reduction occurs when the particles strike or rub against the walls of the confining chamber, but most of the reduction is believed to be caused by interparticle attrition. Internal classification keeps the larger particles in the mill until they are reduced to the desired size.

The suspending gas is usually compressed air or superheated steam, admitted at a pressure of 7 atm through energizing nozzles. The grinding chamber is an oval loop of pipe 25 to 200 mm in diameter and 1.2 to 2.4 m high. Feed enters near the bottom of the loop through a venturi injector. Classification of the ground particles takes place at the upper bend of the loop. As the gas stream flows around this bend at high speed, the coarser particles are thrown outward against the outer wall while the fines congregate at the inner wall. A discharge opening in the inner wall at this point leads to a cyclone separator and a bag collector for the product. The classification is aided by the complex pattern of swirl generated in the gas stream at the bend in the loop of pipe.2 Fluid-energy mills can accept feed particles as large as 12 mm but are more effective when the feed particles are no larger than 100-mesh. They reduce up to 1 ton/h of non sticky solid to particles averaging! to 10 11m in diameter, using 1 to 4 kg of steam or 6 to 9 kg of air per kilogram of product. Loop mills can process up to 6000 kg/h.

Agitated mills: For some ultrafine grinding operations, small batch non rotary mills containing a solid grinding medium are available. The medium consists of hard solid elements such as balls, pellets, or sand grains. These mills are vertical vessels 4 to 1200 L in capacity, filled with liquid in which the grinding medium is suspended. In some designs the charge is agitated with a multiarmed impeller; in others, used especially for grinding hard materials (such as silica or titanium dioxide), a reciprocating central column "vibrates" the vessel contents at about 20 Hz. A concentrated feed slurry is admitted at the top, and product (with some liquid) is withdrawn through a screen at the bottom. Agitated mills are especially useful in producing particles 1 */lm* in size or finer.

Colloid mills: In a colloid mill, intense fluid shear in a high-velocity stream is used to disperse particles or liquid droplets to form a stable suspension or emulsion. The final size of the particles or droplets is usually less than 5 */lm.* Often there is little actual size reduction in the mill; the principal action is the disruption of lightly bonded clusters or agglomerates. Syrups, milk, purees, ointments, paints, and greases are typical products processed in this way. Chemical additives are often useful for stablizing the dispersion.

In most colloid mills the feed liquid is pumped between closely spaced surfaces one of which is moving relative to the other at speeds of 50 m/s or *more.* In the mill shown schematically in Figure 5.9 the liquid passes through the narrow spaces between the disk-shaped rotor and the casing. The clearances are adjustable down to 25 */lm.* Often cooling is required to remove the heat generated. The capacities of colloid mills are relatively low, ranging from 2 or 3 L/min for small mills up to 440 L/min for the largest units.

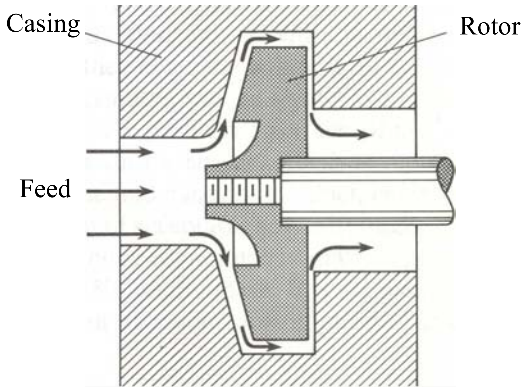

Figure 5.9: Schematic drawing of colloid mill

5.4.4 Cutting Machines

In some size-reduction problems the feed stocks are too tenacious or too resilient to be broken by compression, impact, or attrition. In other problems the feed must be reduced to particles of fixed dimensions. These requirements are met by devices that cut, chop, or tear the feed into a product with the desired characteristics. The sawtoothed crushers mentioned above do much of their work in this way. True cutting machines include rotary knife cutters and granulators. These devices find application in a variety of processes but are especially well adapted to size reduction problems in the manufacture of rubber and plastics.

Knife cutters: A rotary knife cutter, as shown in Figure 5.10, contains a horizontal rotor turning at 200 to 900 r/min in a cylindrical chamber. On the rotor are 2 to 12 flying knives with edges of tempered steel or stellite passing with close clearance over 1 to 7 stationary bed knives. Feed particles entering the chamber from above are cut several hundred times per minute and emerge at the bottom through a screen with 5 to 8 mm openings. Sometimes the flying knives are parallel with the bed knives; sometimes, depending on the properties of the feed, they cut at an angle. Rotary cutters and granulators are similar in design. A granulator yields more or less irregular pieces; a cutter may yield cubes, thin squares, or diamonds.

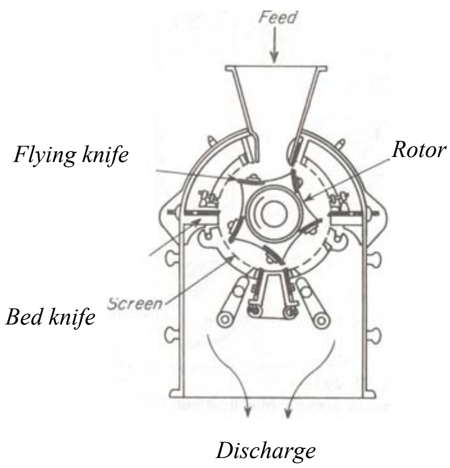

Figure 5.10: Rotary knife cutter

5.5 EFFICIENCY OF SIZE REDUCTION

The ratio of the surface energy created by crushing to the energy absorbed by the solid is the crushing efficiency, η_c . If e_s is the surface energy per unit area, in meter times kg force per square meter, and A_{wb} and A_{wa} are the areas per unit mass of product and feed, respectively, the energy absorbed by a unit mass of the material W_n is

$$W_n = \frac{e_s\left(A_{wb} - A_{wa}\right)}{\eta_c} \tag{5.2}$$

The surface energy created by fracture is small in comparison with the total mechanical energy stored in the material at the time of rupture, and most of the latter is converted into heat. Crushing efficiences are therefore low. Typical crushing efficiencies range between 0.06 and 1 percent.

The energy absorbed by the solid W_n is less than that fed to the machine. Part of the total energy input W is used to overcome friction in the bearings and other moving parts, and the rest is available for crushing. The ratio of the energy absorbed to the energy input is, η_m , the mechanical efficiency. Then, if W is the energy input,

$$W = \frac{W_n}{\eta_m} = \frac{e_s\left(A_{wb} - A_{wa}\right)}{\eta_m \eta_c} \tag{5.3}$$

5.6 ENERGY REQUIREMENT FOR SIZE REDUCTION

The cost of power is a major expense in crushing and grinding, so the factors that control this cost are important. During size reduction, the particles of feed material are first distorted and strained. The work necessary to strain them is stored temporarily in the solid as mechanical energy of stress, just as mechanical energy can be stored in a coiled spring. As additional force is applied to the stressed particles, they are distorted beyond their ultimate strength and suddenly rupture into fragments. New surface is generated. Since a unit area of solid has a definite amount of surface energy, the creation of new surface requires work, which is supplied by the release of energy of stress when the particle breaks. By conservation of energy, all energy of stress in excess of the new surface energy created must appear as heat.

If $\dot{m}$ is the feed rate, the power (P) required by the machine is

$$P = W\dot{m} = \frac{\dot{m}e_s\left(A_{wb} - A_{wa}\right)}{\eta_c \eta_m} \quad (5.4)$$

The average particle size of a mixture of particles is defined in several different ways. Probably the most used is the volume-surface mean diameter, $\overline{D}_s$, which is related to the specific surface area A_w. It is defined by the following equation

$$\overline{D}_s \equiv \frac{6}{\phi_s A_w \rho_p} \quad (5.5)$$

where ϕ_s, spehiricity of particle, and

ρ_p, density of particle, kg/m^3

Substituting A_{wb} and A_{wa} from equation 5.5 in 5.4 we get

$$P = \frac{6\dot{m}e_s}{\eta_c \eta_m \rho_p}\left(\frac{1}{\phi\overline{D}_{sb}} - \frac{1}{\phi\overline{D}_{sa}}\right) \quad (5.6)$$

where $\overline{D}_{sa}$ is mean diameter of feed, and

$\overline{D}_{sb}$ is mean diameter of product

5.6.1 Empirical Relationships

Rittinger's Law: A crushing law proposed by Rittinger in 1867 states that the work required in crushing is proportional to the new surface created. This "law," which is really no more than a hypothesis, is equivalent to the statement that the crushing efficiency, η_c, is constant and, for a given machine and feed material, is independent of the sizes of feed Md product. If the sphericities ϕ_a and ϕ_b are equal and the mechanical efficiency is constant, the various constants in equation (5.6) can be combined into a single constant K_r, known as Rittinger's constant and Rittinger's law written as

$$\frac{P}{\dot{m}} = K_r\left(\frac{1}{\overline{D}_{sb}} - \frac{1}{\overline{D}_{sa}}\right) \quad (5.7)$$

Kick's Law: In 1885 Kick proposed another "law," based on stress analysis of plastic deformation within the elastic limit, which states that the work required for crushing a given mass of material is constant for the same reduction ratio, that is, the ratio of the initial particle size to the final particle size. This leads to the relation

$$\frac{P}{\dot{m}} = K_k \ln\frac{\overline{D}_{sa}}{\overline{D}_{sb}} \quad (5.8)$$

where K_k is a constant.

A generalized relation for both cases is the differential equation

$$d\left(\frac{P}{\dot{m}}\right) = -\frac{Kd\overline{D}_s}{\left(\overline{D}_s\right)^n} \tag{5.9}$$

Solution of equation (5.9) for n = 1, 2 leads to Kick's law and Rittinger's law, respectively.

Both Kick's law and Rittinger's law have been shown to apply over limited ranges of particle size, provided K_k and K_r are determined experimentally by tests in a machine of the type to be used and with the material to be crushed. They thus have limited utility and are mainly of historical interest.

Bond Crushing Law and Work Index : A somewhat more realistic method of estimating ,the power required for crushing and grinding was proposed by Bond in 1952. Bond postulated that the work required to form particles of size D_p from very large feed is proportional to the square root of the surface-to-volume ratio of the product s_p/v_p and $s_p/v_p = 6/\phi_s D_p$, from which it follows that

$$\frac{P}{\dot{m}} = \frac{K_b}{\sqrt{D_p}} \tag{5.10}$$

where K_b is a constant that depends on the type of machine and on the material being crushed. This is equivalent to a solution of equation (5.9) with n = 1.5 and a feed of infinite size. To use equation (5.10), a work index W_i ; is defined as the gross energy requirement in kilowatt hours per ton of feed needed to reduce a very large feed to such a size that 80 percent of the product passes a $100\ \mu m$ screen. This definition leads to a relation between K_b and W_i . If D_p is in millimeters, P in kilowatts, and $\dot{m}$ in tons per hour,

$$K_b = \sqrt{100x10^{-3}}W_i = 0.3162W_i \tag{5.11}$$

If 80 percent of the feed passes a mesh size of D_{pa} millimeters and 80 percent of the product a mesh of D_{pb} millimeters, it follows from equations (5.10) and (5.11) that

$$\frac{P}{\dot{m}} = 0.3162W_i\left(\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}}\right) \tag{5.12}$$

The work index includes the friction in the crusher, and the power given by equation (5.12) is gross power. For dry grinding, the power calculated from equation 5.12 is multiplied by 4/3.

5.7 SCREEN ANALYSIS

The most common method of classification of comminuted product is screening of the ground material through set of sieves, which is also called as ‘screen analysis.’ Bureau of Indian Standards has standardized mesh sizes for screen analysis. The size of openings of standard screens are given in Table 5.1

Table 5.1: Test sieves and their respective sizes

BSS	ASTM	BISS	Width of opening in inches	Width of opening in mm
	4	480	0.1870	4.750
5	6	340	0.1252	3.250
6	7	280	0.1109	2.818
7	8	240	0.0945	2.399
8	10	200	0.0800	2.032
10	12	170	0.0659	1.676
12	14	140	0.0553	1.405
14	16	120	0.0473	1.201
16	18	100	0.0394	1.000
18	20	85	0.0332	0.954
20	-	-	0.0322	0.894
22	25	70	0.0279	0.708
25	30	60	0.0233	0.592
30	35	50	0.0197	0.500
36	40	40	0.0165	0.420
40	-	-	0.0158	0.401
44	45	35	0.0133	0.351
48	-	-	0.0132	0.336
50	-	-	0.0116	0.295
52	50	30	0.0117	0.286
60	60	25	0.0099	0.251
72	70	20	0.0083	0.211
80	-	-	0.0073	0.186
85	80	18	0.0070	0.177
100	100	15	0.0060	0.157
120	120	12	0.0049	0.124
150	140	10	0.0041	0.104
170	170	9	0.0035	0.089
200	200	8	0.0030	0.075
240	220	7	0.0025	0.064
300	270	6	0.0021	0.053
325	-	5	0.0017	0.044
350	325	-	-	0.044
400	-	4	0.0015	0.038

For determination of average particle size in ground food grains, a set of Bureau of Indian Standard Screens is arranged serially in a stack. For food grain flour analysis, a set of BIS sieves No. 100, 70, 50, 40, 30, 20 and 15 with pan and cover are taken. A sample of 250 g of ground product is dried in an oven to constant weight. The dried sample is placed in the topmost sieve and the set is placed on the sieve shaking machine and shaken for 5 minutes.

5.8 FINENESS MODULUS

The fineness modulus indicates the uniformity of grind in resultant product. It is determined by adding the weight fractions retained above each sieve and dividing the sum by 100. An example of determination of fineness modulus is presented below:

Determination of fineness modulus

BIS sieve No.	Weight of material retained	% material retained	Fineness modulus	Average particle size, mm
100	0.0	$7 \times 0.00 = 0.00$		
70	2.8	$6 \times 1.12 = 6.72$		
50	18.4	$5 \times 7.36 = 36.8$		
40	28.7	$4 \times 1.48 = 45.92$	$\frac{279.72}{100} = 2.7972$	$D = 0.135\,(1.366)^{F.M.} = 0.323$ mm
30	90.8	$3 \times 6.32 = 108.96$		
20	98.5	$2 \times 39.4 = 78.8$		
15	6.3	$1 \times 2.52 = 2.52$		
Pan	4.5	$0 \times 1.80 = 0.00$		
		279.72		

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Write short notes on the following:

   i) Colloid mill,
   ii) Knife cutter.

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   ……………………………………………………………………………………

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   ……………………………………………………………………………………

2. Define crushing efficiency and mechanical efficiency.

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   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

3. Typical crushing efficiencies vary between ………….. % and ……….. %.

4. Wheat (4.33 mm size) was milled by a burr mill at two different gaps between the burr stones. 250 g of the flour was analyzed by BIS sieves for particle size determination as given below. The power required to mill wheat, at first setting was 8.0 kW.

   Calculate the power requirement of the mill in second setting using (1) Rettinger's law and (2) Kick's law. The capacity of the mill is 0.2 t/hr.

BIS sieve No.	Mass fraction of flour retained over sieve, g	
	I setting	II setting
100	–	–
70	10.1	1.5
50	16.7	13.3
40	36.0	36.1
30	82.2	74.8
20	96.0	104.6
15	8.0	8.4
Pan	0.0	11.3

5. What is screen analysis?

   ……………………………………………………………………………………

   ……………………………………………………………………………………

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6. What is fineness modulus?

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5.9 LET US SUM UP

We will now recollect the major concepts presented in this unit. Size reduction is an important unit operation to facilitate the processing of food. The four methods of size reduction are crushing, impact, shearing and cutting. A large number of size reducing machines have been developed to meet the specific needs of the raw materials and the food processing. There are two basic parameters which are considered in the design or selection of a size reducing equipment. The first is the energy required for the size reduction. Finer the final particle size, larger will be the energy requirement. Rittinger, Kick, and Bond have proposed different empirical equations for estimating the energy requirement in size reduction. Effort should be made to use one or more of these equations to ensure that the size reduction operation is being carried out efficiently. The other basic parameter is the quality of the final product which is expressed in terms of particle size distribution. Fine mass modulus is computed from the particle size distribution obtained from screen analysis of the final product. It indicates the uniformity of the particle sizes in the final product.

5.10 KEY WORDS

Size reduction/ Comminution : The term *size reduction* is applied to all the ways in which particles of solids are cut or broken into smaller pieces.

Crushing : When an external force applied on a material excess of its strength, the material fails because of its rupture in many directions.

Impact : When a material is subjected to sudden blow of force in excess of its strength, it fails, like cracking of nut with the help of a hammer.

Shearing : It is a process of size reduction, which combines cutting and crushing. The shearing units consist of a knife and a bar.

Cutting : It is a method of size reduction accomplished by forcing a sharp and thin knife through the material.

Grinders : The term *grinder* describes a variety of size-reduction machines for intermediate duty. The product from a crusher is often fed to a grinder, in which it is reduced to powder.

Rittinger's law : A crushing law proposed by Rittinger in 1867 states that the work required in crushing is proportional to the new surface created.

Kick's law : It is based on stress analysis of plastic deformation within the elastic limit, which states that the work required for crushing a given mass of material is constant for the same reduction ratio, that is, the ratio of the initial particle size to the final particle size.

Crushing efficiency : It is the ratio of the actual and the theoretical energy requirement for crushing a material into a given size multiplied by 100.

Screen analysis : Is the most common method of classification of comminuted product obtained using screening of the ground material through set of sieves.

Fineness modulus : The fineness modulus indicates the uniformity of grind in resultant product. It is determined by adding the weight fractions retained above each sieve and dividing the sum by 100.

5.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. i) large capacity,
   ii) should yield a predesired sized product or range of size,
   iii) small power input requirement per unit of product handled, and
   iv) easy and trouble free operation.

2. Solids may be broken in many different ways, but only four of them are commonly used in size-reduction machines:

   i) *compression, e.g. a nutcracker:* Application of external force in excess of the material strength. The particles produced after crushing are irregular in shape and size.

   ii) *impact, e.g. a hammer:* Material is subjected to sudden blow of force in excess of its strength, which causes rupture.

   iii) *attrition, or rubbing, e.g. a file:* It combines cutting and crushing. The shearing units consist of a knife and a bar. If the edge of knife or shearing edge is thin enough and sharp, the size reduction process nears to that of cutting, whereas a thick and dull shearing edge performs like a crusher.

   iv) *cutting. e.g. a pair of scissors:* Accomplished by forcing a sharp and thin knife through the material. In the process minimum deformation and rupture of the material results and the new surface created is more or less undamaged.

3. Size-reduction equipment are: crushers, grinders, ultrafine grinders, and cutting machines.

   They work on the methods of compression, impact, attrition, or rubbing, and cutting. Compression is the characteristic action of crushers. Grinders employ impact and attrition, sometimes combined with compression; ultrafine grinders operate principally by attrition. A cutting action is of course characteristic of cutters, dicers, and slitters.

4. i) *Jaw crusher:* In a jaw crusher feed is admitted between two jaws, set to form a V open at the top. The jaws open and close 250 to 400 times per minute.

   ii) *Toothed roll crusher:* The particle size of the feed to these machines may be as great as 500 mm; their capacity ranges up to 500 tons/h.

   iii) *Hammer mill:* These mills all contain a high-speed rotor turning inside a cylindrical casing. The shaft is usually horizontal Feed dropped into the top of the casing is broken and falls out through a bottom opening.

   iv) *Attrition mill:* In an attrition mill particles of soft solids are rubbed between the grooved flat faces of rotating circular disks. The axis of the disks is usually horizontal, sometimes vertical.

   v) *Tumbling mill:* A cylindrical shell slowly turning about a horizontal axis and filled to about half its volume with a solid grinding medium forms a tumbling mill. For intermediate and fine reduction of abrasive materials tumbling mills are unequaled.

Check Your Progress Exercise 2

1. i) *Colloidal mill:* In a colloid mill, intense fluid shear in a high-velocity stream is used to disperse particles or liquid droplets to form a stable suspension or emulsion. The final size of the particles or droplets is usually less than 5 */lm.* The principal action is the disruption of lightly bonded clusters or agglomerates.

   ii) *Knife cutter:* A rotary knife cutter, as shown in Fig. 5.10, contains a horizontal rotor turning at 200 to 900 r/min in a cylindrical chamber. On the rotor are 2 to 12 flying knives with edges of tempered steel or stellite passing with close clearance over 1 to 7 stationary bed knives. Feed particles entering the chamber from above are cut several hundred times per minute and emerge at the bottom through a screen with 5 to 8 mm openings.

2. Crushing efficiency η_c is the ratio of the surface energy created by crushing to the energy absorbed by the solid whereas mechanical efficiency η_m is the ratio of the energy absorbed to the energy input to any size reduction machine.

3. 0.06 % and 1%.

4. Determination of flour sizes of two setting by sieve analysis:

i) Average particle size of product in I setting:

BIS sieve No.	Weight of material retained	% material retained	Fineness modulus	Average particle size, mm
100	0.0	$7 \times 0.00 = 0.00$	$\frac{295.08}{100} = 2.9508$	$D = 0.135\,(1.366)^{F.M.} = 0.338$ mm
70	10.1	$6 \times 4.04 = 24.24$		
50	16.7	$5 \times 6.68 = 33.40$		
40	36.0	$4 \times 14.40 = 57.60$		
30	83.2	$3 \times 33.28 = 99.84$		
20	96.0	$2 \times 38.40 = 76.80$		
15	8.0	$1 \times 3.20 = 3.20$		
Pan	0.0	$0 \times 0.00 = 0.00$		
		295.08		

ii) Average particle size of product in II setting:

BIS sieve No.	Weight of material retained	% material retained	Fineness modulus	Average particle size, mm
100	0.0	$7 \times 0.00 = 0.00$	$\frac{264.76}{100} = 2.6476$	$D = 0.135\,(1.366)^{F.M.} = 0.308$ mm
70	1.5	$6 \times 0.60 = 3.60$		
50	13.3	$5 \times 5.32 = 26.60$		
40	36.1	$4 \times 14.44 = 57.76$		
30	74.8	$3 \times 29.92 = 89.76$		
20	104.6	$2 \times 41.84 = 83.68$		
15	8.4	$1 \times 3.36 = 3.36$		
Pan	11.3	$0 \times 4.52 = 0.00$		
		264.76		

Determination of Power Requirements:

i) According to Rettinger's Law

$$\frac{P}{\dot{m}} = K_r\left(\frac{1}{\overline{D}_{sb}} - \frac{1}{\overline{D}_{sa}}\right)$$

or $$\frac{8.0}{0.2} = K_r\left(\frac{1}{0.338} - \frac{1}{4.33}\right)$$

or $40 = K_r \times 2.7276$

or $K_r = 14.6649$

Putting the value of K_r in II setting,

$$\frac{P}{0.2} = 14.6649\left(\frac{1}{0.308} - \frac{1}{4.33}\right)$$

or $\quad P = 0.2 \times 14.6649 \times 3.0157 = 8.85$ kW

ii) According to Kick's Law

$$\frac{P}{\dot{m}} = K_k \ln \frac{\overline{D}_{sa}}{\overline{D}_{sb}}$$

or $$\frac{8.0}{0.2} = K_k \ln \frac{4.33}{0.338}$$

or $\quad K_k = 15.6846$

Putting the value of K_k in II setting,

$$\frac{P}{0.2} = 15.6846 \ln \frac{4.33}{0.308}$$

or $\quad P = 8.2916$ kW

5. Screen analysis is a method of classification of comminuted product by screening of the ground material through set of standard sieves.

6. The fineness modulus is an indicator of the uniformity of grind in the resultant/final product. It is determined by adding the weight fractions retained above each sieve and dividing the sum by 100.

5.12 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

UNIT 6 MILLING

Structure

6.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the principles and methods of milling;
- describe the various milling equipments, their efficiencies and relevant methods used for various products; and
- understand the importance of milling, their impact and utility and be able to decide the suitability of different machinery for various products.

6.1 INTRODUCTION

Milling is a general trade name, which normally means reduction of food material into various end products like meal, pulp, flour, splitted products etc. Milling includes cleaning, grading, separating, mixing, pearling, polishing, dehusking, size reduction etc. The meaning of the term milling varies with the commodity. For example, milling of wheat refers to a grinding operation to produce flour, whereas in rice industry, milling refers to overall operations in a rice mill i.e. cleaning, dehuskng, paddy separation, bran removal and grading of milled rice. Milling also refers to extraction of juice, oil or separation of fibre etc.

Most of the agricultural products are in solid form which is generally difficult to handle, compared to liquid and gases. In processing, solids appear in many forms as large irregular pieces or finely divided powders. These particles may be hard and abrasive, soft, brittle, dusty or sticky and plastic. According to the forms of solids, means are to be found to manipulate them into end products and possibly to improve their handling and processing characteristics.

6.2 METHODS OF MILLING

The methods of milling are similar to those discussed in the previous unit on size reduction. However, in case of fruits and vegetables, milling may refer to the juice extraction, cutting for different purposes, etc. For oilseeds it is the expression of oil by compression, solvent extraction etc. and for grains it will vary from one grain to another, for example rice milling would mean hulling, shelling, polishing etc. whereas for wheat it is simple grinding and separation into different fractions and for pulses the dehulling and splitting of the grains.

6.3 MILLING EQUIPMENT

6.3.1 Milling Equipment for Solid Foods

Size reduction of fibrous foods

Most fruits and vegetables fall into the general category of 'fibrous' foods. Fruits and vegetables have an inherently firmer texture and are cut at ambient or chill temperatures. There are five main types of size reduction equipment, classified in order of decreasing particle size, as follows.

1. Slicing equipment consists of rotating or reciprocating blades which cut the food as it passes beneath. In some designs food (Figure 6.1) is held against the blades by centrifugal force. In other (for slicing meats) the food is held on a carriage as it travels across the blade. Harder fruits such as apples are simultaneously sliced and de-cored as they are forced over stationary knives fitted inside a tube. In a similar design (the hydro cutter) foods are conveyed by water at high speed over fixed blades.

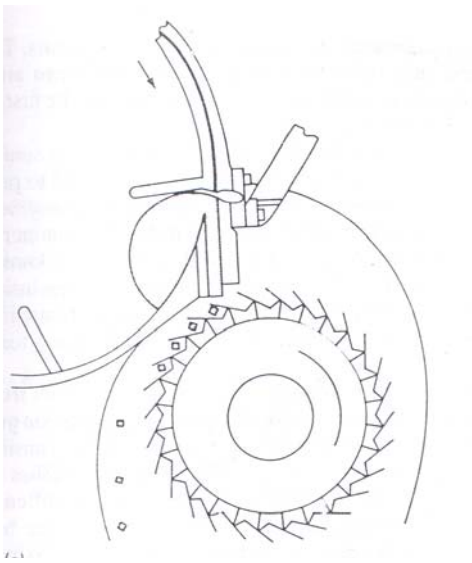

Figure 6.1: Slicing equipment

2. Dicing equipment is for vegetables, fruits and meats. The food is first sliced and then cut into strips by rotating blades. The strips are fed to a second set a rotating knives which operate at right angles to the first set and cut the strips into cubes (Figure 6.2).

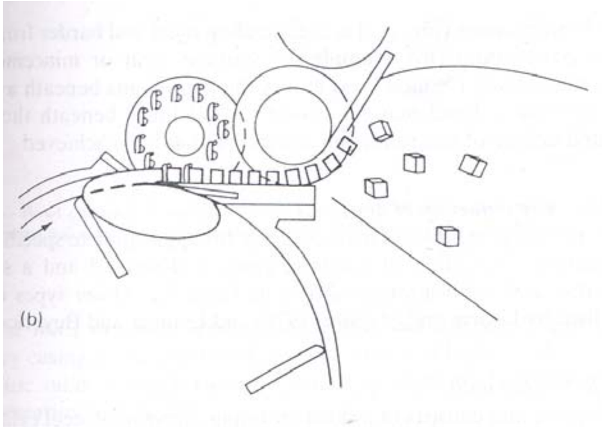

Figure 6.2: Dicing equipment

3. *Flaking equipment* for flaked nuts, fish or meat is similar to slicing equipment. Adjustment of the blade type and spacing is used to produce the flakes.

4. *Shredding equipment.* Typical equipment is a modified hammer mill in which knives are used instead of hammers to produce a flailing or cutting action. A second type of shredder is known as the *squirrel cage disintegrator.* Here two concentric cylindrical cages inside a casing are fitted with knife blades along their length. The two cages rotate in opposite directions and food is subjected to powerful shearing and cutting forces as it passes between them.

5. *Pulping equipment* is used for juice extraction from fruits or vegetables and for pureed and pulped meats. A combination of compression and shearing forces is used in each type of equipment. A rotary grape crusher consists of a cylindrical metal screen fitted internally with high-speed rotating brushes or paddles. Grapes are heated if necessary to soften the tissues, and pulp is forced through the perforations of the screen by the brushes. The size of the perforations determines the fineness of the pulp. Skins, stalks and seeds discarded from the end of the screen. Other types of pulper, including roller presses and screw presses are used for juice expression.

   A *bowl chopper* (Figure 6.3) is used to chop meat and harder fruits and vegetabes into a coarse pulp (for example for sausage meat or mincemeat preserve). A horizontal, slowly rotating bowl moves the ingredients beneath a set of high-speed rotating blades. Food may be passed several times beneath the knives until required degree of size reduction and mixing has been achieved.

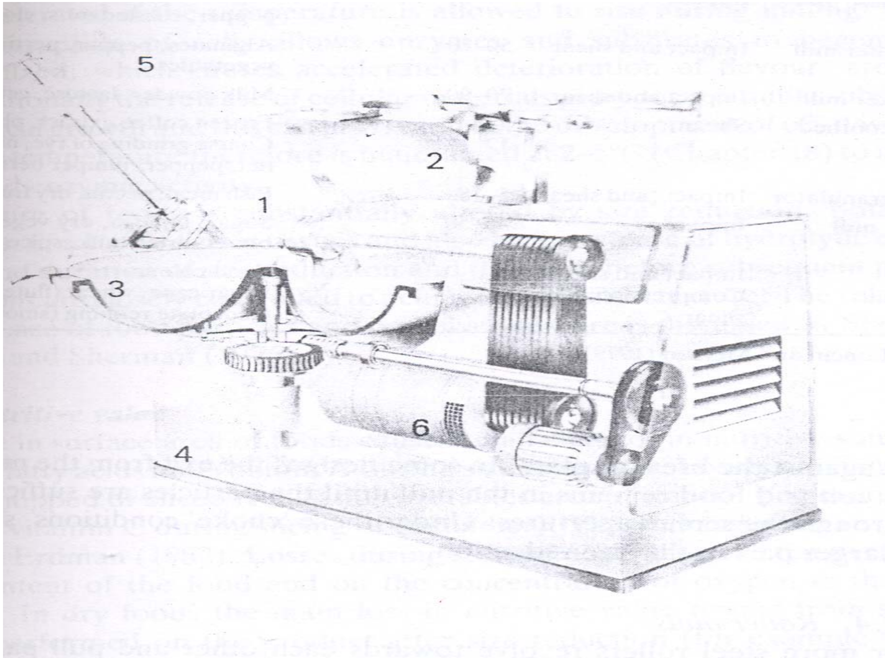

Figure 6.3: Bowl chopper: 1) Cutting blades, 2) Cover, 3) Rotating cutter bowl, 4) Casings; 5) Rotating unloader disc; 6) Main motor drive

Size reduction of dry foods

There are a large number of mills available for application to specific types of food.

Ball mills

This type of mill consists of a slowly rotating, horizontal steel cylinder which is half filled with steel balls 2.5-15cm in diameter. At low speeds or when small balls are used, shearing forces predominate. With larger balls or at higher speeds, impact forces become more important. A modification of the ball mill named the *rod mill* has rod instead of balls to overcome problems associated with the balls sticking in adhesive foods.

Disc mills

There are a large number of designs of disc mill. Each type employs shearing forces for fine grinding or shearing and impact forces for coarser grinding. For example,

1. single-disc mills in which food passes through an adjustable gap between a stationary casing and a grooved disc which rotates at high speed,

2. double-disc mills in which two discs rotate in opposite directions to produce greater shearing forces, and

3. pin-and-disc mills which have intermeshing pins fixed either to the single disc and casing or to double discs. (Figure 6.4)

These improve the effectiveness of milling by creating additional impact and shearing forces.

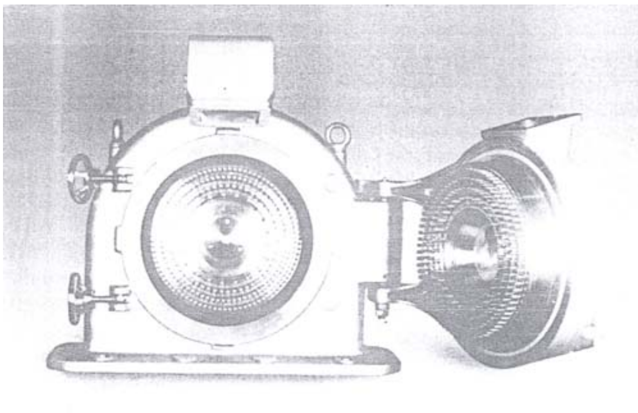

Figure 6.4: Pin and disc mill

Hammer mills

A horizontal cylindrical chamber is lined with a toughened steel breaker plate. A high-speed rotor inside the chamber is fitted with hammers along its length (Figure 6.5). In operation, food is disintegrated mainly by impact as the hammers drive it against the breaker plate. In some designs the exit from the mill is restricted by a screen and food remains in the mill until the particles are sufficiently small do pass through the screen apertures. Under these ‘choke’ conditions; shearing forces play a larger part in the size reduction.

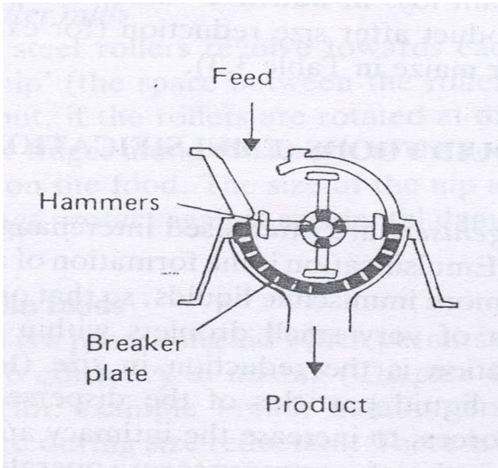

Figure 6.5: Hammer mill

Roller mills

Two or more steel rollers revolve towards each other and pull particles of food through the ‘nip’ (the space between the rollers) (Figure 6.6). The main force is compression but, if the rollers are rotated at different speeds, or if the rollers are fluted (shallow ridges along the length of the roller), there is an additional shearing force exerted on the food. The size of the nip is adjustable for different foods and overload springs protect against accidental damage from metal or stones.

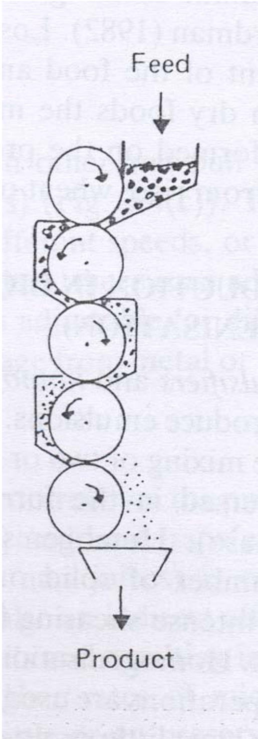

Figure 6.6: Roller mill

6.3.2 Milling Equipment for Liquid Foods (Emulsification and Homogenisation)

The terms emulsifiers and homogenisers are often used interchangeably for equipment used to produce emulsions. Emulsification is the formation of a stable emulsion by the intimate mixing of two or more immiscible liquids, so that one (the dispersed phase) is dispersed in the form of very small droplets within the second (the continuous phase). Homogenisation is the reduction in size (to 0.5-3µm) and increase in number of solid or liquid particles of the dispersed phase, by the application of intense shearing forces, to increase the intimacy and stability of the two substances. Homogenisation is therefore a more severe operation than emulsification. Both operations are used to change the functional properties or eating quality of foods. They have little or no effect on nutritional value or shelf life.

The four main types of homogenizer are as follows:

1. high-speed mixers;
2. pressure homogenisers;
3. colloid mills;
4. ultrasonic homogenisers.

High-speed mixers

Turbine or propeller-type high-speed mixers are used to pre-mix emulsions of low-viscosity liquids. They operate by shearing action on the food at the edges and tips of the blades.

Pressure homogenisers

These consist of a high-pressure pump, operating at 10,000-70,000kPa, which is fitted with a homogenizing valve on the discharge side. An example of one of the many different designs of valve is shown in Figure 6.7. When liquid is pumped through the small, adjustable gap (300μm) between the valve and the valve seat, the high pressure results in a high liquid velocity (8400 ms^{-1}). There is then an almost instantaneous drop in velocity as the liquid emerges from the valve. These extreme conditions of turbulence produce powerful shearing force. The collapse of an air bubbles (termed *cavitation)* and impact forces created in some valves by placing a hard surface (a *breaker ring)* in the path of the liquid further reduce the globule size. In some foods (for example milk products) there may be inadequate distribution of the emulsifying agent over the newly formed surfaces, which causes fat globules to clump together. A second similar valve is then used to break up the clusters of globules. Pressure homogenisers are widely used before pasteurisation and ultrahigh-temperature sterilisation of milk, and in the production of salad creams, ice cream and some sauces.

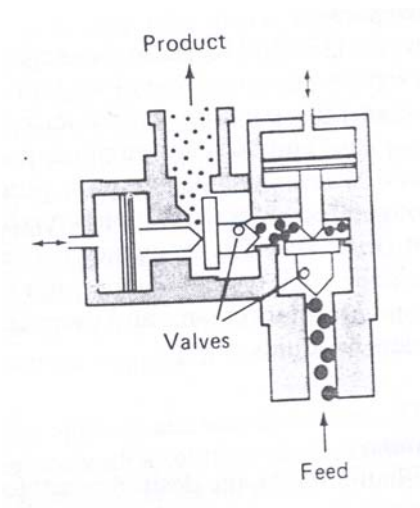

Figure 6.7: Hydraulic two-stage pressure homogenizing valve

Colloidal mills

These homogenisers are essentially disc mills. The small (0.05-1.3 mm) gap between a vertical disc which rotates at 3000-15000 rev min^{-1}, and a similar-sized stationary disc creates high shearing forces. They are more effective than pressure homogenisers for high-viscosity liquids, but with intermediate-viscosity liquids they tend to produce larger droplet sizes than pressure homagenisers do. Numerous designs of disc, including flat, corrugated and conical shapes, are available for different applications. Modifications of this design include the use of two counter-rotating discs or intermeshing pegs on the surface of the discs to increase the shearing action. For highly viscous foods (for example peanut butter, meat or fish pastes) the discs may be mounted horizontally (the *paste mill).* The greater friction created in viscous foods may require these mills to be cooled by recirculating water.

Ultrasonic homogenisers

High-frequency sound waves (18-30 kHz) cause alternate cycles of comprssion and tension in low-viscosity liquids and cavitation of air bubbles, to form an emulsion with droplet sizes of 1-2μm. In. operation, the dispersed phase of an emulsion is added to the continuous phase and both are pumped through the homogenisers at pressures of 340-1400kPa. The ultrasonic energy is produced by a metal blade, which vibrates at its resonant frequency. Vibration is produced either electrically or by the liquid movement (Figure 6.8). The frequency is controlled by adjusting the clamping position of the blade. This type of homogeniser is used for the production of salad creams, ice cream, synthetic creams and essential oil emulsions. It is also used for dispersing powders in liquids.

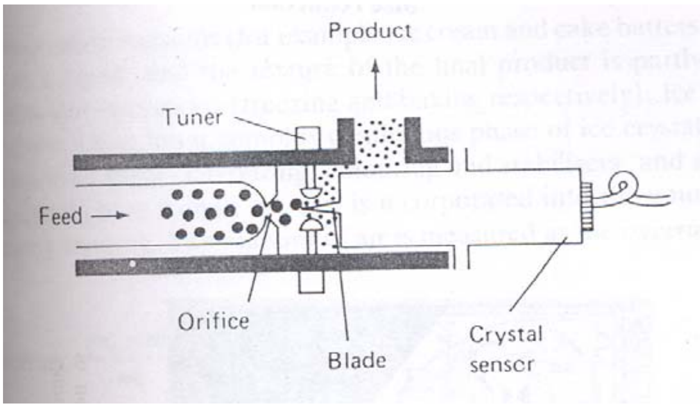

Figure 6.8: Ultrasonic homogenizer

6.4 EFFICIENCY OF MILLING

To achieve good results from any milling machine the followings should be given due care, (1) feed should be *of* proper size and feeding rate should be uniform, (2) hard or unbreakable material is not-allowed to enter the mill, (3) after grinding the product is removed as soon as possible, and (4) there should be some arrangement to remove the heat generated during milling operation.

Determination of power requirement for a particular grinding job is difficult. The exact amount of power requirement depends on type of material, moisture content of feed, material feed rate, type and condition of mill, product particle size requirement, nature of abrasive surface etc.

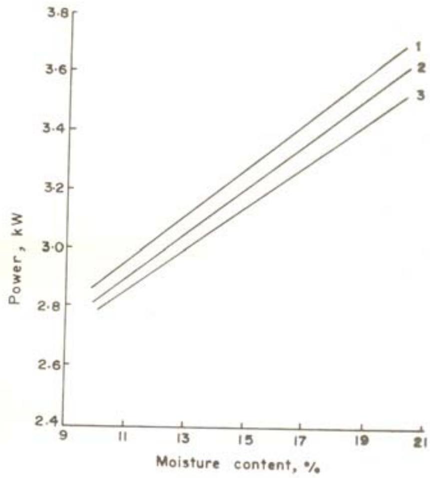

Figure 6.9: Effect of moisture content on power requirement: 1) 2800 rpm, 2) 2680 rpm, 3) 2560 rpm.

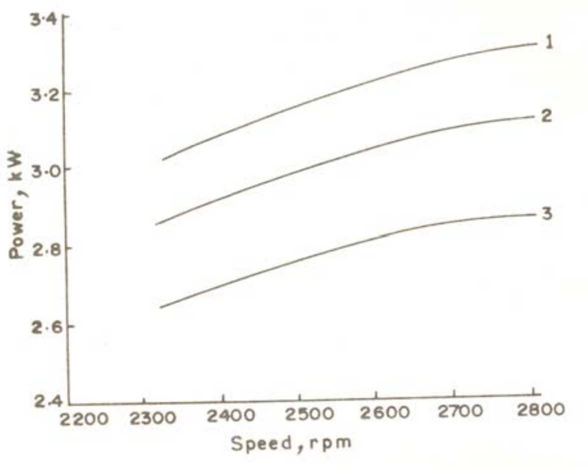

Figure 6.10: Effect of speed of operation on power requirement: 1) 17.9% moisture content, 2) 15% moisture content, 3) 11.8% moisture content.

Grains at higher moisture content are more difficult to grind than dry grains. The effect of moisture upon the power requirement for grinding of wheat with swinging hammer mill is shown in Figure 6.9. It was also found that fibrous materials require more power for grinding than non-fibrous material. At increased rotational speed the power requirement also increases (Figure 6.10).

Energy consumption: In size reduction of solids, bulk of the energy input is dissipated as heat energy. This energy raises the temperature of milled product, the mill and the air. Some of the energy is lost during vaporization of grain moisture. Comparatively small fraction of energy input is utilized for creation of new surfaces. During grinding of grains the temperature rise is observed to be 20°C or more in emery burr mills. This temperature rise may partially decompose some materials. Therefore, there should be some arrangement to remove this heat. In some abrasive mills provision is made to draw ambient air for cooling purposes.

6.5 METHODS OF SEPARATION

The unit operation of separation can involve separating a solid from a solid, as in the peeling of potatoes or the shelling of nuts; separating a solid from a liquid, as in the many types of filtration; or a liquid from a solid, as in pressing juice from a fruit. It might involve the separation of a liquid from a liquid, as in centrifuging oil from water, or removing a gas from a solid or a liquid, as in vacuum removal of air from canned food in vacuum exhausting.

One of the commonest forms of separating in the food industry is the hand sorting and grading of individual units as in the case of vegetables and fruit. However, because of the high cost of labour, mechanical and electronic sorting devices have been developed. Difference in colour can be detected with a photocell and off-colour products rejected. This can be done at enormous speeds with automatic rejection of discoloured or mouldy nuts or kernels of grain that flow past the photocell. In the case of peanuts to be made into peanut butter, each peanut individually passes through a light beam that activates a jet of air to blow the discoloured peanuts from the main stream when an off-colour changes the amount of reflected light. Light shining through eggs can detect blood spots and automatically reject such eggs. Automatic separation according to size is, easily accomplished by passing fruits or vegetables over different size screens, holes, or slits.

The skins of fruits and vegetables may be separated using a lye peeler (Figure 6.11). Peaches, apricots, and the like are passed through a heated lye solution. The lye or caustic softens the skin to where it can be easily slipped from the fruit by gentle action of mechanical fingers or by jets of water. Differences in the density of the fruit and skin can then be used to float away the removed skin.

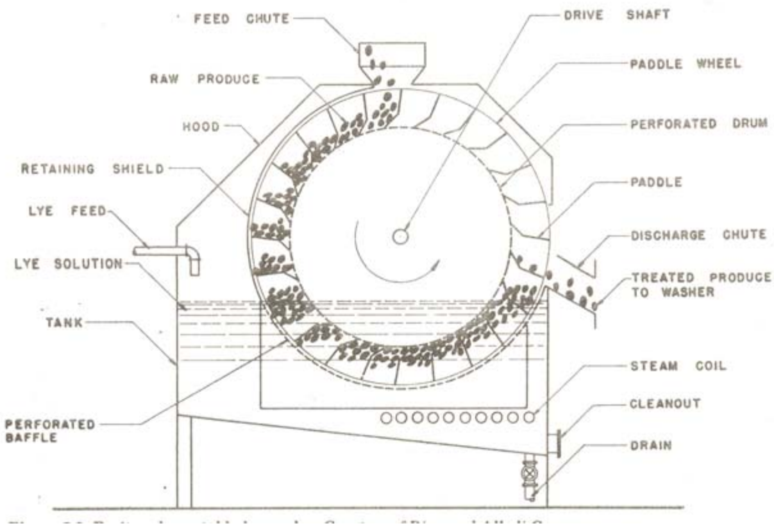

Figure 6.11: Lye peeler

To separate corn oil from corn kernels, the germ portion of the corn first is separated from the rest of the kernel by milling; then the oil is separated from the germ by applying high pressure to the germ in an oil press. Similarly, pressure is used to squeeze oil out of peanuts, soybeans, and cottonseeds. The traces of oil can be removed from the pressed cake by the use of fat solvents. There then remains the separation of the oil from the solvent.

Crystallization is used to separate salt from seawater, or sugar from sugar cane juice. Here, evaporation of some of the water causes super saturation, and crystals form. Since crystals are quite pure, this is also considered a purification process. The crystals are then separated from the suspending liquid by centrifugation.

Newer methods of separation include several techniques involving manufactured membranes with porosities or permeabilities capable of separations and fractionations at the colloidal and macromolecular size level. Ultrafiltration uses membranes of such porosity that water and low-molecular-weight salts, acids, and bases pass through the membrane but larger protein and sugar molecules are retained. This selective separation process, carried out at ambient temperatures, avoids the heat damage to sensitive food constituents that is often associated with water evaporation at high temperatures. Further, removal of acids and salts with the water prevents their concentration, which would otherwise be detrimental to sensitive retained solids.

6.6 RELEVANT STANDARDS

There are many relevant standards developed by the Bureau of Indian Standards, Codex Alimentarieus, etc. which needs to be followed for different methods and processes. These can be obtained from respective organizations.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Write short notes on the following:

i) Slicer	ii) Flaker
iii) Dicer	iv) Pulper

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2. Write short notes on the following:

i) Bad mill	ii) Disc mill
iii) Roller mill	iv) Colloidal mill

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6.7 LET US SUM UP

Milling is one of the important unit operations in fruit and vegetable processing industry. A suitable and adequate milling would prove to be a boon for any food industry because a proper selection would reduce the energy consumption and enhance the quality and profitability of a food processing industry.

6.8 KEY WORDS

Slicing equipment : It consists of rotating or reciprocating blades which cut the food as it passes beneath.

Dicing equipment : Dicing equipment is for vegetables, fruits and meats. The food is first sliced and then cut into strips by rotating blades. The strips are fed to a second set of rotating knives which operate at right angles to the first set and cut the strips into cubes.

Flaking equipment : *Flaking equipment* for flaked fish, nuts or meat is similar to slicing equipment. Adjustment of the blade type and spacing is used to produce the flakes.

Pulping equipment : *Pulping equipment* is used for juice extraction from fruits or vegetables and for pureed and pulped meats. A combination of compression and shearing forces is used in each type of equipment.

6.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. All the short notes should contain the following points:
   - Principle of operation.
   - Suitability of use.
   - Final product and
   - Its relative importance in a food industry.
2. All the short notes should contain the following points:
   - Principle of operation.
   - Suitability of use.
   - Capacity
   - Final product and
   - Its relative importance in a food industry.

6.10 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.
2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

UNIT 7 MATERIAL HANDLING

Structure

7.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the principles and concepts of material handling;
- know various available material handling devices and their drive mechanisms; and
- understand the importance of material handling and decide the suitability of different machinery for various uses.

7.1 INTRODUCTION

Material handling is an activity that uses the right method to provide the right amount of the right material at the right place, at the right time, in the right sequence, in the right position and at the right cost. Material handling includes a number of operations that can be executed either by hand (manual) or by mechanical means or devices to convey material and to reduce the human drudgery. Mechanical handling devices aim to lighten the work of human labour. After harvesting, crops are moved, transported or conveyed from place to place. In earlier periods all these operations were manual. The crops were primary processed and bagged/boxed by human labour. Foods were transported several times through storage and processing plants, and the processed food products were conveyed manually to consumers. Thus, foods were handled too much involving increased costs and human drudgery. But in modem times, some of the mechanical devices have replaced human labour, other supplement it or in some case make possible to handle larger quantities of grains per unit human labour.

7.1.1 Material Handling Principles

Various principles involved in material handling are:

1. Thorough study the problem and identification of problem areas, constraints and goals.
2. Develop plans, which meets our basic requirements, is flexible and includes desirable features.
3. Integrate various activities such as receiving, shipping, production assembly, etc.
4. Make the unit load size as large as possible.
5. Use the cubic space as effectively as possible.
6. Where possible standardize equipment and procedures.
7. Design equipment and methods that allow effective interaction between humans and machines.
8. When evaluating handling equipment, examine energy requirement and costs.
9. To the extent possible, use methods and equipment that minimize adverse effects on the environment.
10. Where possible mechanize methods to achieve efficiency.
11. Use methods and equipments that provides the maximum flexibility.
12. Simplify, combine or if possible eliminate unnecessary moves or equipment.
13. Use gravity as much as possible to transfer material keeping in mind safety and product damage.
14. Use safe handling equipment and methods.
15. To the extent possible computerize, so as to achieve better material and information control.
16. Integrate material and information flows.
17. Evaluate each alternate layout and select the most effective and efficient one.
18. Evaluate each alternate solution and select one based on cost per unit handled.
19. Perform preventive maintenance.
20. Develop equipment replacement plan based on after-tax life cycle costs.

7.1.2 Systems Approach to Materials Handling

When establishing methods of materials handling, a systems approach covering raw materials, materials in process and finished products is needed, in order to optimize flow rates in the correct sequence throughout the production process and to avoid bottlenecks or shortages. Additionally the flow of foods through a factory should be as simple as possible to reduce costs, to avoid confusion, which could lead to the contamination of processed foods by raw foods, to improve working conditions and to attain the benefits.

7.2 MATERIAL HANDLING DEVICES

7.2.1 Conveyors

Conveyors are widely used in all food processing industries for the movement of solid materials, both within unit operations and between operations (Table 7.1). There are a large number of conveyor designs, produced to meet specific applications. Common types include the following.

1. **Belt conveyor:** This is an endless belt, which is held under tension between two rollers, one of which is driven. The belts may be stainless steel mesh or wire, synthetic rubber, or a composite of canvass, steel and polyurethane or polyester. Flat belts are used to carry packed foods, and trough-shaped belts are used for bulk materials. Belts may be inclined up to 45°, if they are fitted with cross slats to prevent the product from slipping. Metal or wooden slatted conveyors are used instead of belts for greater load bearing and a reduced risk of damage to the conveyor.

2. **Roller conveyor** and skate wheel conveyor. Free-running (unpowered) rollers or wheels are either horizontal, to allow packed foods to be pushed along, or slightly inclined for transport under gravity. Rollers are heavier and stronger than wheels and therefore able to carry heavier loads. However, they are more difficult to start and stop, and more difficult to use around corners. Steeper inclines produce greater acceleration of packages, and a fall of approximately 10 cm in 3 m is sufficient for most purposes. Powered conveyors are used horizontally, or at a maximum inclination of 10-12°.

Table 7.1: Applications of materials-handling equipment

	Conveyors	Elevators	Cranes and hoists	Trucks	Pneumatic equipment	Water flumes
Direction						
Vertical up		*	*			
Vertical down		*	*		*	
Incline up	*	*			*	
Incline up	*	*			*	*
Horizontal	*			*	*	
Frequency						
Continuous	*	*			*	*
Intermittent			*	*		
Location served						
Point	*	*			*	*
Path	*				*	*
Limited area			*			
Unlimited area				*		
Height						
Overhead	*	*	*		*	
Working height	*			*	*	*
Floor level	*		*	*		*
Underfloor	*				*	*

Materials						
Packed	*	*	*	*		
Bulk	*	*	*	*	*	
Solid	*	*	*	*	*	*
Liquid				*	*	*
Service						
Permanent	*	*	*		*	*
Temporary			*	*		

3. **Chain conveyor:** This is used to move churns, barrels, crates and similar bulk containers by placing them directly over a driven chain, with protruding lugs, located at floor level. A similar monorail conveyor is used for moving meat carcasses on an overhead track.

4. **Screw conveyor:** This consists of a rotating helical screw inside a metal trough. It is used to move bulk foods (for example flour and sugar) and small-particulate foods (for example peas or grains). The main advantages are the uniform, easily controlled discharge, the compact cross-section (without a return conveyor) and total enclosure to protect the product and to prevent contamination. They may be horizontal or vertically inclined but are generally limited to a maximum length of 6 m as, above this, high friction forces result in excessive power consumption.

5. **Vibratory conveyors:** These impart a vertical movement to food, to raise it a few millimetres off the conveyor, and a forward movement, to move the food along the conveyor. The amplitude of vibration is adjusted to control the speed and direction of movement. This precise control makes vibratory conveyors useful as feed mechanisms for processing equipment. They are also useful, for moving sticky or friable foods (snack foods).

6. **Flight conveyors:** Here, bulk material (for example grain or flour) is dragged through an enclosed channel by an endless chain fitted with hooks or flights. Chain speeds are low (6-10m min^{-1}) and the inclination is limited to 30°, above which the material slips back.

7.2.2 Elevators

Four common types of elevator are as follows:

1. **Bucket elevators:** consist of metal or plastic buckets fixed between two endless chains. They have a high capacity for free-flowing powders and particulate foods. The shape and spacing of the buckets, the method of discharge and the speed of the conveyor (15-100 m min^{-1}) control the flow rate of materials.

2. **Magnetic elevators:** are used for conveying cans within canneries. They have a positive action in being able to hold the cans in place and are thus able to invert empty cans for cleaning and operate at high speeds with minimal noise.

3. **Flight elevators**: are essentially inclined flight conveyors. They have flexibility in use for a wide range of free-flowing bulk foods, high capacity and good space utilization.

4. **Pneumatic elevators:** Powders or small-particulate foods are suspended in air, which is re-circulated at 1000-1700 m min^{-1} inside a system of pipes. The air velocity is critical; if it is too low, the solids settle out whereas, if it

is too high, there is abrasion damage to the pipe surfaces. Similar equipment is used to classify foods and to dry foods. A build-up of static electricity is prevented by control over the moisture content of the food and earthing the equipment. This is necessary when conveying powders to minimize the risk of dust explosions. This type of equipment has a smooth operation and cannot be overloaded. It has few moving parts; low maintenance costs and only requires a supply of compressed air at 700 kPa.

7.3 PRINCIPAL DRIVE MECHANISMS, SUITABILITY OF USE AND ENERGY REQUIREMENT FOR MATERIAL HANDLING

7.3.1 Belt Conveyors

A belt conveyor is an endless belt operating between two pulleys with its load supported on idlers. The belt may be flat for transporting bagged material or V-shaped or some other enclosed shape for moving bulk grains. The belt conveyor consists of a belt, drive mechanism and end pulleys, idlers and loading and discharge devices (Figure 7.1). Belt conveyors have antifriction bearing, therefore, these have a high mechanical efficiency. Material carried by belt conveyor lie still on the surface of belt or there is no relative motion between the product and belt. This results in generally no damage to material. Belt can be run at higher speeds, so, large carrying capacities are possible. Horizontally the material can be transported to longer distance but there is a limit to carry the material on elevation. A properly designed and maintained belt conveyor has long service life and low operating costs. Compared to other types of horizontal conveying system, the initial cost of belt conveyor is high for short distances. But for longer distances, the initial cost of belt conveying system is competitive or low.

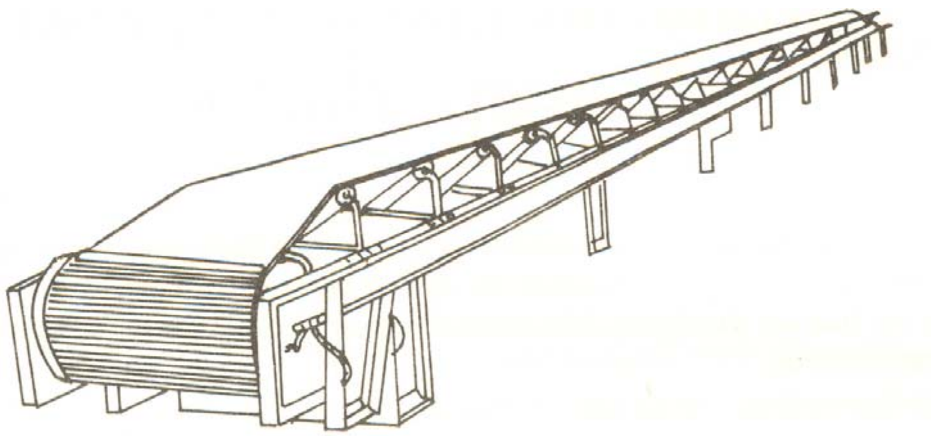


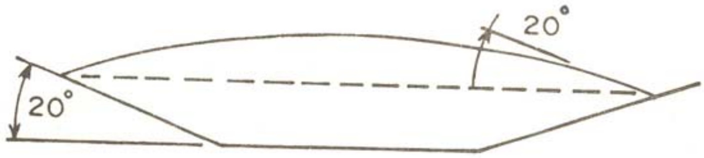
Figure 7.1: Belt conveyor

The design of belt conveyor system is based on available space, horizontal conveying length and conveying lift, characteristics of the material to be conveyed and capacity requirement. On the basis of overall requirement and information, the following will be determined to design a belt conveyor, belt width, belt speed, required horsepower, maximum belt tension and breaking strength of the belt, diameter of the pulleys and idlers and quality of belt (thickness).

The first step in the design of a belt conveyor with a specified conveying capacity is to determine the speed and width of the belt. The belt speed should be selected to minimize product spillage. The selection of belt width will depend upon the capacity requirement, speed of operation, angle of inclination of belt conveyor, trough angle and depth. The capacity of belt conveyor can be given by;

$$\text{Capacity, m}^2\text{/hr} = (\text{area of cross-section, m}^2) \times (\text{belt-speed, m/min}) \times 60 \quad (7.1)$$

The load cross sections of troughed belt is shown in Figure 7.2.



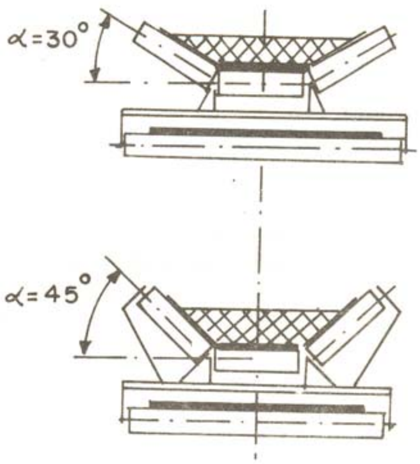


Figure 7.2: Various troughing configurations

The horsepower required for operation of belt conveyor for conveying grains can be calculated by the following equations. These equations are based on lift, friction resistance of the belt and pulleys and trippers. The values of constants are given in Table 7.2.

$$HP_1 = \frac{\text{Beltspeed, m/min.}}{0.3048} \text{x} \frac{(A+B)(3.281L)}{100} \quad (7.2)$$

$$HP_2 = \text{Capacity, t/hr} X \frac{0.48 + 0.01L}{100} \quad (7.3)$$

$$HP_3 = \frac{\text{Lift, m}}{0.3048} \text{x} 1.015 \text{x} \frac{\text{Capacity, t/hr}}{1000} \quad (7.4)$$

where, L = length of belt, m
A & B are constants.

Table 7.2: Values of constants A and B

Belt width, cm	Constants		Additional horsepower for tripper
	A	B	
36	0.20	0.00140	0.70
41	0.25	0.00140	0.85
46	0.30	0.00162	1.00
50	0.30	0.00187	1.40
60	0.36	0.00224	1.70
76	0.48	0.00298	2.50

The majority of belt conveyors for transporting bulk material use some type of rubberised conveyor belt made up of carcass. The pull of load is taken by the longitudinal strength of belt while the transverse strength supports the load. The belt is protected from damage by a rubber cover. The thickness of top rubber cover varies with thickness and wear resistance requirements.

7.3.2 Screw Conveyors

The screw conveyor consists of a tubular or U-shaped trough in which a shaft with spiral screw revolves. The screw shaft is supported by end and hanger bearings. The rotation of screw pushes the grain along the trough. A typical screw conveyor is shown in Figures 7.3a and b. The screw conveyor is used for conveying of products generally for short distances. Screw conveyor requires relatively high power and is more susceptible to wear than other types of conveyors. The pitch of a standard screw, which is the distance from the center of one thread to the center of the next thread, is equal to its diameter.

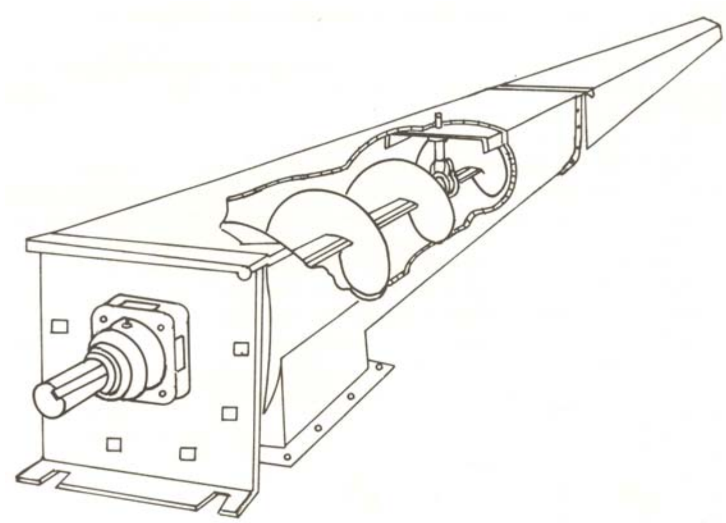


Figure 7.3a: Screw conveyor

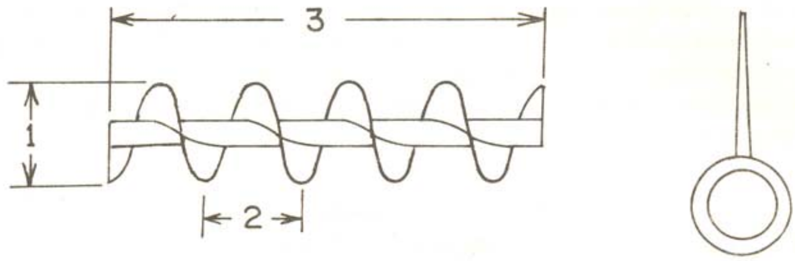


Figure 7.3b: Screw conveyor-details: 1) Screw diameter, 2) Pitch of screw, 3) Screw length

As the screw conveyor's driving mechanism is simpler, and no tensioning device is required, the initial cost of the conveyor is lower than any other conveyor with the same length and capacity. The main parts of a screw conveyor are, screw blade, screw shaft, coupling, trough, cover, inlet and outlet gates, bearings and drive mechanism.

The screw conveyor is generally used to move grains horizontally. However, it can also be used at any angle up to *90°* from the horizontal, but the capacity correspondingly reduced as *per* the inclination of conveyance.

The screw basically consists of a shaft and the screw blade or flight. The flight is a continuous one-piece helix, shaped from a flat strip of steel welded onto the shaft. The screw shaft is usually a joint less tube with thick sides and a high tensile strength to reduce the weight. The thickness of the steel strip helix decreases from the inner edge to the outer edge. Troughs of screw conveyor have different shapes. Most common is U shaped trough. In an enlarged or *flared* trough the sidewalls become wider at the top (Figure 7..4). This type of trough is usually used *for* conveying non-easy flowing materials, which may have lumps. The tubular trough is completely closed with circular cross-section and mostly used *for* conveying materials at inclination or *for* vertical lift.

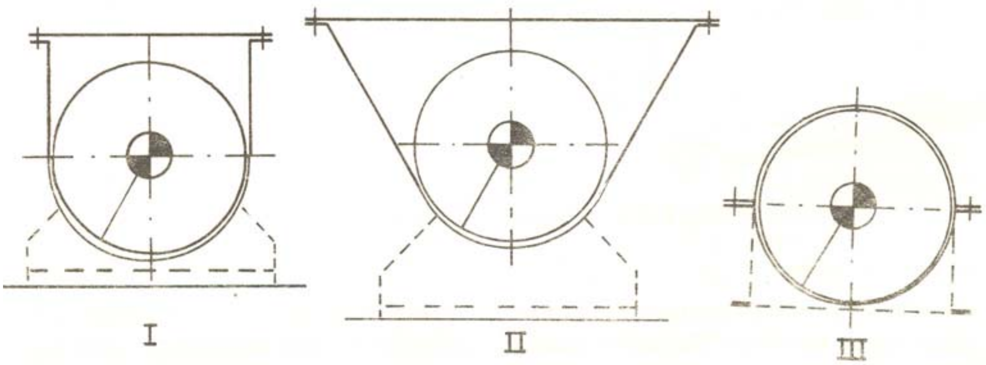


Figure 7.4: Various shapes of screw conveyor trough I) U-trough, II) Flared trough, III) Tubular trough.

For operational reasons, some gap is provided between the edge of the screw blade and the trough walls. Due to this gap it is not possible to completely empty the trough of a horizontal screw conveyor. If the screw conveyor is used to convey different materials, mixing of products is possible. Also when the food particles are pressed between the screw edge and trough walls, they can be damaged. During conveyance the kernels are also subjected to continuous friction with the trough walls. Screw conveyor may be designed for clockwise or counterclockwise rotation. The change in direction of rotation does not affect the capacity.

The capacity of screw conveyor is influenced by the screw diameter, inclination of the screw blade, speed of the blade, shaft diameter and cross-section of loading. The theoretical conveyance capacity of the screw conveyor can be given by the following equation.

$$\text{Capacity Q, m}^3\text{/hr} = 47.2\ (D^2 - d^2) \times p \times n \qquad (7.5)$$

where, D = screw diameter, m
d = shaft diameter, m
p = pitch, m
n = rpm

The theoretical capacity is more than the actual capacity because of screw housing clearance and the loading factor (Figure 7.5).

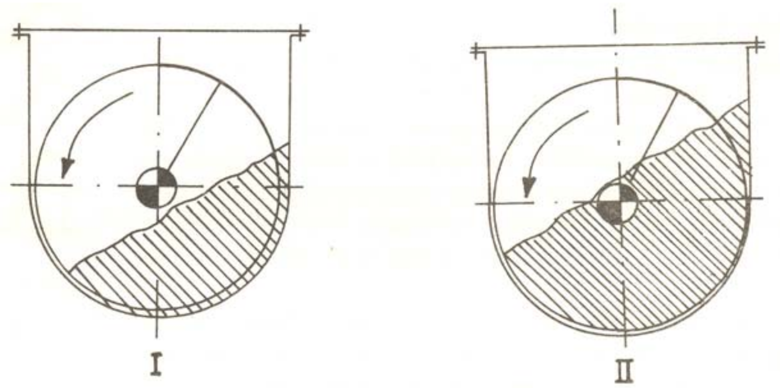


Figure 7.5: Screw conveyor loading factor I) 30% loading, II) 55% loading

The power requirement of screw conveyors for horizontal operation may be determined by the following equation:

$$\text{HorsePower} = \frac{QLWF}{4500} \qquad (7.6)$$

where, Q = conveyor capacity, m^3/min.
L = conveyor length, m
W = bulk material weight, kg/m3
F = material factor (for paddy 0.4)

If the calculated horsepower is less than 1.0, double the value.

Horsepower	=	1 to 2	multiply the value by 1.5
Horsepower	=	2 to 4	multiply the value by 1.25
Horsepower	=	4 to 5	multiply the value by 1.1

For horsepower values of more than 5, no correction is required.

Screw conveyors can be operated in an inclined position. In this case, the material will be conveyed upward. The capacity of inclined screw conveyor decreases than the horizontal operation. A screw conveyor inclined 15 degrees will carry about 75% of the rated horizontal capacity. At an inclination of 25 degrees, it will carry about 50% of the rated horizontal capacity.

7.3.3 Pneumatic Elevator

The pneumatic conveyor moves granular materials in a closed duct by a high velocity air stream. Pneumatic conveying is a continuous and flexible transportation method. The material is carried in pipelines either by suction or blowing pressure of air stream. The granular materials because of high air pressure are conveyed in dispersed condition. For dispersion of bulk material, air velocities in the range of 15-30 m/s is necessary. The pneumatic conveying system needs a source of air blowing or suction, means of feeding the product into the conveyor, and a cyclone or receiving hopper for collection of products. There are three basic systems of pneumatic conveying. These are pressure or blowing system, suction or vacuum system, and combined push-pull or suck-blow system.

In blowing or positive pressure systems, the product is conveyed by using air pressures greater than the atmospheric pressure. This system consists of a fan or blower, an air-lock feeder for introducing the product into the system, ducts and suitable air and product separating device. The product is fed into the pneumatic conveying system from the bottom of a hopper.

The feeder should be able to feed product at a specified rate in a pneumatic conveying system from the supply hopper at one pressure to the conveying pipeline at another pressure. The most common type of feeder is rotary feeder (Figure 7.6). It consists of a bladed rotor with pockets at the inlet port. When the rotor moves, the products are dropped to outlet port and to the conveying pipeline. The advantage of rotary feeder is that it meters the supply of products into the conveying pipeline. It also affects the air lock, which is necessary for the operation of the system.

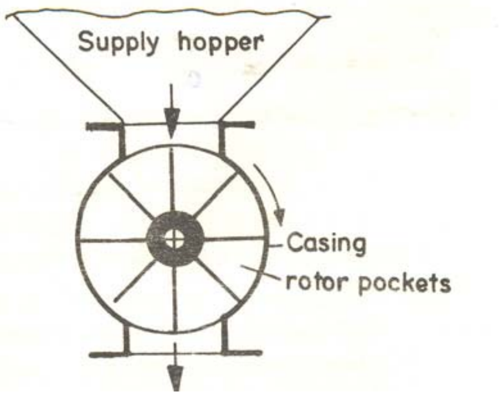


Figure 7.6: Rotary feeder for pneumatic conveyor

The selection of air mover is the most important aspect of the design of a pneumatic conveying system. In design, the two factors, (1) supply air pressure and (2) the volumetric flow rate of air should be considered. .

The supply pressure's value depends upon the working pressure drop required for the length of conveying line and across the filter. The magnitude of air pressure depends on the conveying length and the properties of the product to be conveyed. The volumetric flow rate of air depends on the necessary air velocity and pipe or duct size used in the system. In pneumatic conveying systems, fans and blowers with high volumetric flow rates and low pressures to positive displacement compressors producing high pressures are used. .

For separation of product particles from air, air-product separators are used. Cyclones are mostly used to collect the particles. Cyclone is a device, which removes the bulk of the product particle from the conveying air stream by centrifugal force. In some cyclone, a fabric filter is attached to remove residual dust and fine product particles from the air stream (Fig. 7.7). The conveying air is first passed through the cyclone and then it goes to the fabric filter for secondary separation of finer particles.

Limitations of Pneumatic Conveying

1. Erosion of solid surfaces and equipment surfaces by solid particles with conveying air stream. The rate of erosion of solid surfaces increased remarkably with conveying of abrasive products.

2. In case of bends or misaligned sections, the erosion problem becomes severe. In industrial installations, the erosion of duct system poses major problem in the operation of pneumatic conveying system.

3. In a pneumatic conveying system, chances of repeated impacts between the particles and the solid surfaces are high. Due to such impacts, product degradation results, because of this changes take place in the product size distribution and consequently the market value diminishes.

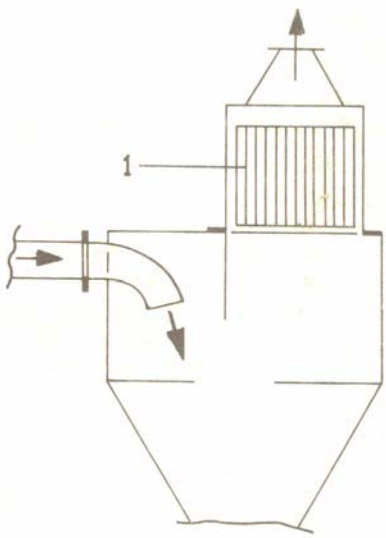


Figure 7.7: Separation of product particles from air by means of fabric filter

7.3.4 Bucket Elevator

A bucket elevator consists of buckets attached to a chain or belt that revolves around two pulleys one at top and the other at bottom. The vertical lift of the elevator may range between few meters to more than 50 m. Capacities of bucket elevators may vary from 2 to 1000 t/hr. Bucket elevators are broadly classified into two general types, 1) spaced bucket elevators and 2) continuous bucket elevators. The above two types are further subdivided into various classes.

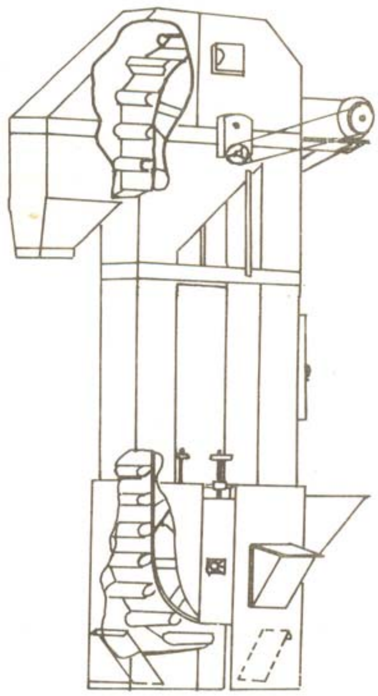


Figure 7.8: Bucket elevator

The spaced bucket elevators are further classified as, 1) centrifugal discharge elevators, 2) positive-discharge elevators, 3) marine leg elevators and 4) high-speed elevators. The continuous bucket elevators are classified as 1) super capacity bucket elevators, and 2) internal-discharge bucket elevators.

The spaced-bucket centrifugal discharge type is most commonly used for elevating the grains. A centrifugal discharge bucket elevator is shown is Figure 7.8. The bucket elevator is a very efficient device for the vertical conveyance of bulk grains. Bucket elevators with belts are employed in food industries for vertical conveyance of grains, derivatives and flours. Bucket elevators are usually mounted at a fixed location, but they can also be mounted in a mobile frame. Bucket elevators have high capacities and it is a fairly cheap means of vertical conveyance.

It requires limited horizontal space and the operation of conveying is enclosed in housing, thus it is dust free and fairly quite. The bucket elevator has limited wear problem since the product is enclosed in buckets. In a bucket elevator, the conveyor belt with buckets runs over pulleys at the upper and lower ends. The top pulley is driven pulley while the lower pulley is return and tension pulley. Buckets are usually made of steel or plastic and are bolted onto the belt. The buckets may be enclosed in a single housing called leg, or two legs may be used. The return leg may be located at some distance from the elevator leg. The houSing or legs are also made of steel, are welded or bolted together, and are dust tight. The curved hood is designed for proper centrifugal discharge of the grains. The boot can be loaded from the front or back or both (Figure 7.9). The various discharge types of bucket elevators are shown in Figure 7.10. The product flow is discharged either by means of gravity or centrifugal force.

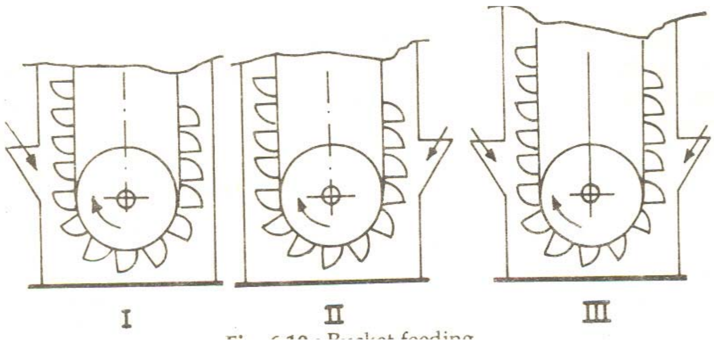


Figure 7.9: Bucket feeding I) Front feed, II) Back feed, III) Combined feed.

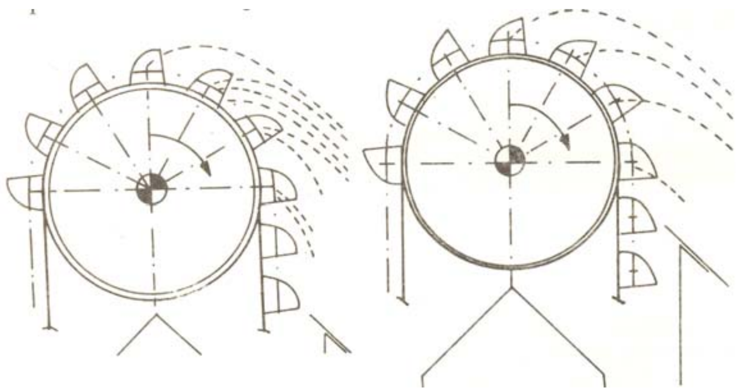


Figure 7.10: Bucket elevator's discharge methods: 1) Low speed gravitational discharge, 2) high speed centrifugal discharge.

The bucket elevator's capacity mainly depends on bucket size, conveying speed, bucket design and spacing, the way of loading and unloading, the bucket and the characteristic of bulk material. Belt speed is the first critical factor to consider. Bucket elevators with a belt carrier can be used at fairly high speeds of 2.5 to 4 m/ s. The speed of the belt depends on the head pulley speed. If the belt speed is too low, the discharge of the grains becomes more difficult, with too high speed the buckets are not fed well. A properly designed bucket elevator driven at the correct speed will make a clean discharge.

The gravitational discharge occurs with non-adhesive bulk material elevated at low speed and by means of buckets mounted closely together. In such discharge, the contents of a bucket flow over the rear side of the previous bucket. With purely centrifugal discharge, complete contents of a bucket are projected towards the discharge chute. Such type of discharge is obtainable with high belt speeds and smaller diameter drive pulleys. In elevating of grains the discharge from bucket elevators is a combination of centrifugal and gravitational discharge. Part of the bucket contents is projected by the centrifugal force, the rest flows out by gravity.

When a product mass turns around a pulley, it is influenced by two forces, (1) gravitational force, which is oriented downwards and (2) centrifugal force. The magnitude of the centrifugal force which is oriented outward can be given by

$$c_f = \frac{WV^2}{gr} \tag{7.7}$$

where, W = weight of grain
V = velocity of product mass
g = acceleration due to gravity .
r = radius of the wheel plus one-half of the projection of the bucket

For optimum centrifugal discharge, and calculation of the speed of head pulley, the resultant force is zero, it means that the centrifugal force is equal to the force of gravity, or, $c_f = W$

Hence, $W = \dfrac{WV^2}{gr}$ or, $V = \sqrt{gr}$

Since velocity, $V = \dfrac{2\pi nr}{60}$ (n = rpm) (7.8)

$$\frac{2\pi nr}{60} = \sqrt{gr} \quad \text{or,} \quad n = \frac{60\sqrt{g}\sqrt{r}}{2\pi\sqrt{r}\sqrt{r}} = \frac{29.9}{\sqrt{r}} \qquad (7.9)$$

The bucket elevator's capacity may be calculated by the following equation.

Elevator capacity, *m^3/hr* = bucket capacity, *m^3* x number of bucket per meter of belt x belt speed, m/min. × 60 (7.10)

$$Capacity, t/hr = \frac{Capacity, m^3/hr \times material density, kg/m^3}{1000} \qquad (7.11)$$

Drive mechanism

The drive mechanism of a bucket elevator is located near the elevator head. At the elevator head, the belt is turned around the drive pulley. Drive motor with gearbox and couplings are mounted on a rigid and separate frame. For serving the elevator head section, the drive mechanism, a working platform is provided. Usually a ladder is provided for access to this platform.

The theoretical horsepower requirement for the bucket elevator can be calculated by the following equation.

$$hp = \frac{QHF}{4500} \qquad (7.12)$$

where, Q = capacity of bucket elevator, kg/min
H = lift of elevator, m
F = factor; 1.5 for elevators loaded on the up side and 1.2 for elevators loaded on the bottom side

The theoretical horsepower should be increased 10-15% to provide for friction and power requirements for loading, power transmission and drive losses.

7.4 INTERACTION BETWEEN MATERIAL AND HANDLING DEVICES

Interaction between the material and the handling device is one of the important considerations for the selection of a suitable material handling device. The suitability of the different material handling devices for food products have been already discussed in section 7.2 and 7.3.

7.5 SELECTION OF MATERIAL HANDLING DEVICES

The selection of proper conveying system is important for ease in operation and getting desired capacity for a particular product. Before selecting a conveying system, the following principles should be taken into account.

1. The conveying device has to be selected according to the characteristics of the products being conveyed
2. The stability of the conveyor must be ensured under all normal working and climatic conditions.
3. The capacity of conveying and speed rating should be maintained at specified limits.
4. The dead load of the conveyor should be low in relation to the weight of transported product.
5. In a conveying system possibility of use of gravity should be taken into consideration.
6. The capacity of handling/conveying equipment should match with the capacity of processing unit or units.
7. Spillage of conveyed products should be avoided. Pollution of the environment due to noise or dust by the conveying system should also be avoided.

The four basic issues (Figure 7.11) relating to integration of material handling (MH) equipment into a manufacturing environment are (1) extraction to extract information about individual material handling tasks, (2) filtering and matching of individual tasks with individual resources, without regard to system performance and economy, (3) aggregation of tasks into sets that are then matched with technologies and (4) system selection and specification.

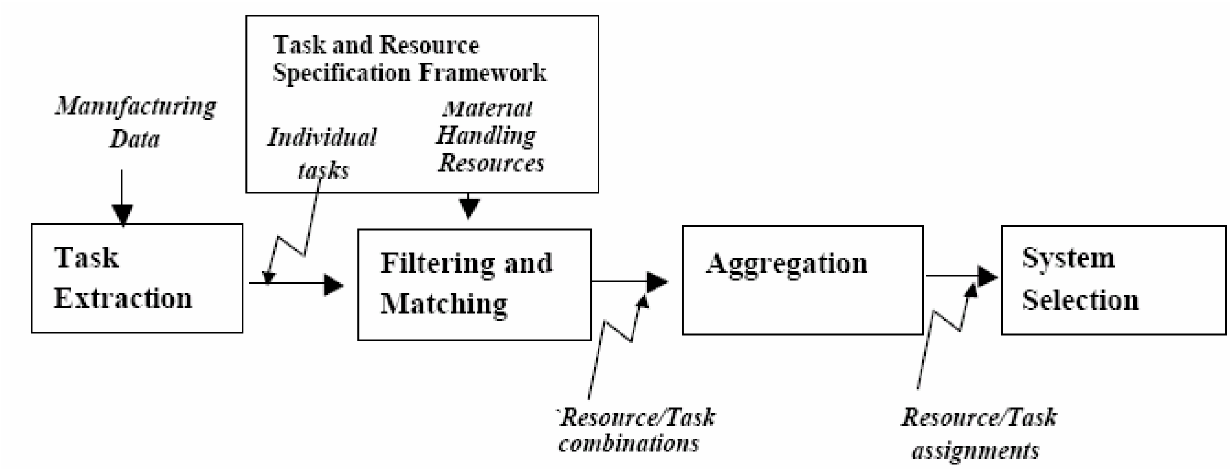


Figure 7.11: Major steps of procedure for selecting and specifying material handling equipment for manufacturing.

7.6 COST OF MATERIAL HANDLING

The cost of material handling will depend on (i) material to be carried, (ii) distance over which the material is to be carried, (iii) height of material elevation, (iv) efficiency of the material handling device, (v) maintenance cost of the material handling device, (vi) cost of the device, (vii) life span of the material handling device, (viii) method of loading and unloading of the material onto and from the device, etc.

There is no thumb rule as to which material handling device would be economical for a particular operation. It has to be therefore, decided keeping in mind the actual activity to be undertaken.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Write a short note on the importance of material handling in food industry.

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2. Enlist any five principles of material handling.

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3. Write short notes on the following:

i) Belt conveyor
ii) Screw conveyor
iii) Bucket elevator

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4. Differentiate between conveyors and elevators.

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5. A belt conveyor carrying 1 $m^3$of material having a bulk density of 600 kg/m^3 per meter length of belt is moving at 2.5 m/min. The length and width of the belt is 100 m and 60 cm respectively. Calculate the capacity and horsepower requirement of the conveyor.

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6. A screw conveyor having shaft and screw diameters as 15 and 25 cm respectively rotates at 500 rpm. Considering the pitch of the screw to be equal to its shaft diameter, calculate the capacity of the conveyor. If the conveyor length is 10 m, bulk density of the material is 500 kg/m^3, calculate the horsepower requirement of the conveyor assuming the material factor as 0.5.

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7. A bucket elevator having 100 buckets of 0.2 m^3 capacity is running at a speed of 1 m/s. The length of the elevator is 10 m and material bulk density is 700 kg/m^3. Calculate the capacity and horsepower requirement of the bucket elevator.

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7.7 LET US SUM UP

Conveyors and elevators are the two much important classes of material handling equipment. Once we know the characteristics of the material to be handled and other critical requirements, one could select an appropriate conveyor/elevator. These conveyors/elevators could be chain, belt, bucket, screw, pneumatic, magnetic, vibratory types. Proper selection and design of capacity and power units leads to the minimization of the cost of material handling.

7.8 KEY WORDS

Material handling : It is a method of carrying the material from one place to another either horizontally or vertically.

Selection of material handling equipment : It is a method of adoption of the most appropriate handling device to suite ones own requirement.

Elevators : Used for transfer of materials in horizontal direction where the angle of lift is very steep.

Power requirement : It is the amount of energy required per unit time to operate any system.

Capacity : It is the total material that any given system can carry for a given time and energy utilized.

7.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Importance of material handling in food industry:
2. Five principles of material handling are:
   - Thoroughly study the problem and identify problem areas, constraints and goals.
   - Develop plans, which meets our basic requirement, is flexible and includes desirable features.
   - Integrate various activities such as receiving, shipping, production assembly, etc.
   - Make the unit load size as large as possible.
   - Use the cubic space as effectively as possible.
3. i) A belt conveyor is an endless belt operating between two pulleys with its load supported on idlers. The belt may be flat for transporting bagged material or V-shaped or some other enclosed shape for moving bulk grains.

   ii) The screw conveyor consists of a tubular or U-shaped trough in which a shaft with spiral screw revolves. The screw shaft is supported by end and hanger bearings. The rotation of screw pushes the grain along the trough.

iii) A bucket elevator consists of buckets attached to a chain or belt that revolves around two pulleys one at top and the other at bottom. The vertical lift of the elevator may range between few meters to more than 50 m. Capacities of bucket elevators may vary from 2 to 1000 t/hr.

4. Conveyors are mainly used for horizontal or inclined transmission of materials. The inclination is limited to the material transported, whereas, elevators can be used to lift materials vertically irrespective of the material they carry.

5. i) Calculate capacity by using equation 7.1.
   ii) Hp = Hp1 (Equation 7.2) + Hp2 (Equation 7.3) + Hp required for tripper (Table 7.2)

6. i) Calculate capacity by using equation 7.5.
   ii) Calculate horse power by using equation 7.6.

7. i) Calculate capacity by using equation 7.11.
   ii) Calculate horse power by using equation 7.12.

7.10 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

UNIT 8 TRANSPORTATION AND PACKAGING

Structure

8.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the principles and methods of transportation;
- describe the various types of packaging material and their selection for food packaging; and
- decide the suitability of different types of packaging material.

8.1 INTRODUCTION

The prevention of food losses is of vital concern to growers as well as processors, and various measures can be applied at all stages between the grower and the consumer in order to reduce wastage, improve food security and generate income and profit.

The use of appropriate packaging and transportation is one of these measures and when properly applied can have a dramatic effect, reducing losses and ensuring that products reach the customer in the best possible condition. Appropriate packaging and transportation can range from the proper use of containers in which to transport produce to local markets, through to sophisticated systems that can extend the shelf-life of a processed foodstuff for a year or more.

Essentially, packaging:

- Aims to provide protection from all types of external damaging effects;
- Is an integral part of the food processing chain and helps both producers and consumers to transport, store, sell, purchase and use foods more efficiently;
- Is a means of ensuring that the product is delivered to the user in known quantities and in the expected condition for a specified shelf-life;
- Is a means of making the food more attractive in order to promote its use and increase sales;
- Conveys information to customers about the type of food they are buying, how to prepare it, its shelf-life, and that it conforms to relevant food legislation.

Thus, at its simplest level, packaging contains and protects, while at its most sophisticated it takes on additional roles such as preserving, selling, information and enhancing the convenience element of the product.

The type of packaging required depends mainly on the nature of the product, the length of time and conditions under which it will be transported and stored before use, the final market for which it is intended and local food laws. If the food is to be consumed near to where it is produced and eaten quickly after processing, little or no packaging may be required. However, if the product is aimed, for example, at a distant export market, the packaging requirements can become extremely complicated. At the point of sale, good packaging and presentation helps to attract customers, and may provide extra convenience in use.

8.2 METHODS OF TRANSPORTATION AND THEIR SUITABILITY WITH RESPECT TO PRODUCT

Damage in transit is one of the oldest problems in packaging. The hazard that packages meet cannot be anticipated and are mostly accidents. Protection is required against the average hazard encountered and not against the most severe one. The distribution system of a consumer good in its simplest form is shown below.

PRODUCTION
↓
PACKING
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FACTORY GODOWN
↓
SALES GODOWN
↓
DISTRIBUTION GODOWN
↓
RETAILERS STORAGE
↓
RETAIL STORE SHELF
↓
CONSUMER SHELF
↓
RECYCLING - OTHER USE
↓
REUSE

Figure 8.1: Distribution system for a consumer good

The distribution hazards encountered in any system which needs to be taken care of to decide the packaging material depends on the mode of transportation, method of handling and storage. The transportation modes and hazards there in are:

8.2.1 Bullock or Horse Drawn Cart

- Used for short distance transport.
- Stacking height upto 5 feet.
- Drop height upto 5 feet.
- Bumping due to rough road surface.
- Directional placements of packages may not be possible.

8.2.2 Road-Trucks

- Used for long and short distances.
- Package dimensions should suit the body dimensions for maximum space utilization.
- Door to door service.
- Delays in journey during rainy season.
- Freight rates generally higher than that of rail.
- Lower standard packages accepted than in rail.

Hazards

- Stacking height upto 7 feet.
- Drop height upto 4 feet.
- Puncturing of fibreboard boxes by protruding bolts etc. of the sides.
- Bumping due to irregular road surfaces.

8.2.3 Rail-Goods Trains

- Tran-shipment necessary.
- Pilferage is a major problem.
- Proper handling instructions essential.
- Packages can be sent on railways risk.
- Packages are to conform to rules and regulations of the railways.
- Door to door delivery possible only by container service.
- No problem for inter-state transport.
- Less interruption of journey even in rainy season.

Hazards

- Stacking height upto 8 feet.
- Vibration due to rail joints and track conditions.
- Shunting shock.
- Very high temperature (upto 70°C) in steel wagons in summer.

8.2.4 Sea-Ship

- Packages are carried in ship holds and decks.
- Normally the journey is preceeded and followed by other modes of transport. Hence packages should conform to the regulation of other modes also.
- Require proper handling instructions in different languages and figures.
- Freight rates by Cubic volume.

Hazards

- Stacking height upto 10-15 feet.
- Manual or machine handling.
- Very high relative humidity in the holds.
- Salt spray water on the decks or on the docks.
- Vibration due to engine propeller
- Swaying due to waves.

8.2.5 Air-Cargo

- High freight charges and hence lighter packages to be used.
- Limitations on size & weight of packages.
- Less journey time.
- Better handling.
- No cooling facility available.

Hazard

- High frequency vibration due to engine.
- Low temperature and pressure when flying at high altitudes.

8.3 SPECIAL REQUIREMENTS FOR TRANSPORATION OF AGRICULTURAL MATERIALS

Agricultural materials are living and continue all the physiological functions even after harvest. Therefore, it requires special care during its handling, packaging and transportation. Fresh as well as processed products meant for human consumption are of utmost importance keeping in view the seriousness of different health hazards associated with the contamination of foods during transportation. Most of the requirements with respect to the advantages, hazards and precautions are discussed in section 8.2 and 8.7.

8.4 TRANSPORATION COSTS

Transportation costs would depend on many factors like methods of transportation, efficiency of transportation, input costs for transportation, allowable time limit for transportation, losses during transportation, cost of the produce that is being transported and other associated costs. All these must be taken into consideration before deciding the method of transportation so as to minimize losses and optimize the profits.

8.5 ROLE OF PACKAGING OF AGRICULTURAL AND FOOD MATERIALS

Packaging is an integral part of food processing. It performs two main functions: to advertise foods at the point of sale, and to protect foods to a pre-determined degree for the expected shelf life. The main factors that cause deterioration of foods during storage are:

- mechanical forces (impact, vibration, compression or abrasion),
- climatic influences that cause physical or chemical changes (UV light, moisture, oxygen, temperature changes),
- contamination (by micro-organisms, insects or soils) and
- pilferage, tampering or adulteration.

In addition the package should not influence the product (for example by migration of toxic compounds, by reactions between the pack and the food or by selection of harmful micro-organisms in the packaged food). Other requirements of packaging are smooth efficient and economical operation on the production line, resistance to breakage (for example fractures, tears or dents caused by filling and closing equipment, loading/unloading or transportation) and minimum total cost.

The main marketing considerations are:

- the brand image and style of presentation required for the food,
- flexibility to change the size and design of the containers, and
- compatibility with the method of handling distribution, and the requirements of retailer.

In summary, the package should be aesthetically pleasing, have a functional size and shape, retain the food in a convenient form, possibly act as a dispenser and be suitable for easy disposal or re-use. The package design should also meet any legislative requirements concerning labelling of foods.

8.5.1 Packaging Functions

The functions of packaging are numerous and include such purposes as protecting *raw* or processed foods against spoilage and contamination by an array of external hazards. Packaging serves as a barrier in controlling oxygen and water levels, facilitates ease of use, offers adequate storage, conveys information and provides evidence of possible product tampering. It achieves these goals by assisting in the following manners:

- Preserving against spoilage of colour, flavour, odour, texture, and other food qualities.
- Preventing contamination by biological, chemical, or physical hazards.
- Controlling absorption and losses of O_2, water vapour and other volatile substances.
- Facilitating ease of using product contents-such as packaging that incorporates the components of a metal together in meal "kits" (e.g. tacos).
- Offering adequate storage before use-such as stockable, resealable, pourable.
- Preventing/indicating tampering with contents by tamper-evident labels.
- Communicating information regarding ingredients, nutrition facts, manufacturer name and address, weight, bar code information, and so forth via package labelling.
- Marketing-standards of packaging, including worldwide acceptability of certain colours and picture symbols vary and should be known by the processor; packages also carry such information as merchandising messages, health messages, recipes, and coupons.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Describe the importance of packaging and transportation in the production and processing chain of foods.

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2. Enlist the suitability and hazards related to the following modes of transport.

   i) Rail-good train
   ii) Air cargo

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3. Enlist three factors that cause deterioration of foods during storage.

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4. List any five functions of packaging.

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8.6 PACKAGING OF LOW AND HIGH MOISTURE FOODS

Packaging containers of foods both low and high moisture are classified as primary, secondary, and tertiary. A ***primary*** container is the bottle, can, drink box, and so forth that contains food. It is a direct-food-contact surface and is, therefore, subject to approval by competent authority, which tests for the possible migration of packaging materials into food.

Several primary containers are held together in ***secondary*** containers, such as corrugated fiberboard boxes (commonly, but not correctly, referred to as cardboard), and do not have direct food contact. In turn, several secondary containers are bundled into ***tertiary*** containers such as corrugated boxes or overwraps that prepare the food product for distribution or palletizing. They offer additional food protection during storage and distribution where errors, such as dropping and denting or crushing cartons, may occur. They prevent the brunt of the impact from falling on the individual food container.

8.6.1 Packaging Materials

In choosing the appropriate packaging for their product, packers must consider many variables. For example, *canners* must make packaging choices based on cost, product compatibility, shelf life, flexibility of size, handling systems, production line filling and closing speeds, processing reaction, impermeability, dent and tamper resistance, and consumer convenience and preference. Processors who use films for their product must select film material based on its "barrier" properties that prevent oxygen, water vapour, or light from negatively affecting the food.

The most common food packaging materials include metals, glass, paper, and plastic. Some examples of these leading materials appear in the following text.

Metal

Metals such as steel and aluminum are used in cans and trays. A metal can forms a hermetic seal, which is a complete seal against gases and vapor entry or escape, and it offers protection to the contents. The trays may be reusable, or disposable recyclable trays, and either steamtab1e or No. 10 can size. Metal is also used for bottle closures and wraps.

1) **Steel** has a non-corrosive coating of tin inside, thus the name "tin can," where as **tin-free steel** (TFS) relies on the inclusion of chromium or aluminum in place of tin. Steel is manufactured into the traditional three-piece construction can, which includes a base, cylinder, and lid, and also a two-piece can, consisting of a base and cylinder in one piece without a seam, and a lid. The latter are lightweight and stackable. The five primary types of steel vacuum closures include side seal caps, lug caps, press-twist caps, snap-on caps, and composite caps.

2) **Aluminum** is easily formed into cans with hermetic seals. It is also used in trays and for wraps such as aluminum foil, which provide an oxygen and light barrier. It is lighter in weight than steel and resists corrosion.

Glass

It is derived from metal oxides such as silicon dioxide (sand). It is used in forming bottles or jars (which receive hermetic seals) and thus protects against water vapour or oxygen loss. The thickness of glass must be sufficient to prevent breakage from internal pressure, external impact, or thermal stress. Glass coatings, similar to eyeglass coatings of silicones and waxes, may be applied to glass containers in order to minimize damage-causing nicks and scratches.

Paper

It is derived from the pulp of wood and may contain additives such as aluminium particle laminates, plastic coating, resins, or waxes. These additives provide burst strength (strength against bursting), wet strength (leak protection), and grease and tear resistance, as well as barrier properties that assure freshness, protect the packaged food against vapour loss and environmental contaminants, and increase shelf life.

Varying thicknesses of paper may be used to achieve thicker and more rigid packaging.

- Paper is thin (one layer) and flexible, typically used in bags and wrappers. Kraft (or strong" in German) paper is the strongest paper. It may be bleached and used as butcher wrap or may remain unbleached and used in grocery bags.
- Paperboard is thicker (although still one layer) and more rigid. Ovenable paperboard is made for use in either conventional or microwave ovens by coating paperboard with PET polyester.
- Multilayers of paper form *fiberboard,* which is recognized as "cardboard".

Plastic

It has shrink, nonshrink, flexible, semirigid, and rigid applications, and varies in its degree of thickness. Important properties of the many types of plastics that make them good choices for packaging material include the following:

- Flexible and stretchable.
- Lightweight.
- Low-temperature formability.
- Resistant to breakage, with high burst strength.
- Strong heat sealability.
- Versatile in its barrier properties to O_2, moisture, and light.

8.7 PACKAGING FOR PHYSICAL DISTRIBUTION AND TRANSPORATION

Any package is functionally incomplete if the goods received at the distribution is unacceptable. Hence, the secondary and tertiary packaging, which can withstand the physical abuses during handling, transportation and storage, is also very important. The most commonly used conventional transport containers for fresh and processed food includes wooden boxes, corrugated fibreboard boxes, plastic crates, high-density polyethylene drums, steel drums and pails. Sacks are also generally used to bring fresh produce to the processing centres from the fields. The selection of a transport container is based on the characteristics of the product, the kind of handling and transportation hazards likely to be encountered at various stages of the distribution system.

8.7.1 Transportation Containers

The primary function is to contain the article. It may need to be designed to prevent pilferage during the journey between manufacturer and ultimate consumer. A third and the most important property of the shipping container is its compatibility with the product contained within it. The other important aspect of a shipping container is labelling regarding what it contains, how much it contains and when it is packed and possibly sales promotion.

Wooden Containers

Wooden containers are one of the earliest shipping container since wood was then available in plenty. But presently, use of wood is discouraged as our forests are depleting year by year. There is a stiff competition from fibreboard containers both in terms of cost and performance. Still the wood container is widely used for perishables in the domestic market. The requirement for such a purpose include:

- Aeration required for the dissipation of heat and exchange of gases.
- High stacking strength and stability.
- There should be no fungus and mould growth when stored at high relative humidity.
- Dimensional stability.

Corrugated Fibre Board Boxes (CFB)

The corrugated fibreboard is made of paperboard liners and corrugating medium. The structure of corrugated fibreboard consists of a fluting medium running in a sinusoidal wave form between the two liners, thus separate the liners by a distance to obtain good stiffness.

Unbleached virgin coniferous craft is most appropriate for liner materials. It has a high tearing resistance and stiffness and a low rate of moisture absorption from air. Other materials like straw, bagasse, bamboo etc. have lower performance particularly when exposed to higher relative humidities. In case these materials are used, their substance has to be increased at least by 50% to get the satisfactory performance.

In case of packaging for fruits and vegetables, ventilation holes for the dissipation of heat and exchange of gases are very much essential. Careful attention must be given to the number, size. shape and position of these holes without sacrificing the strength of the box.

Inserts and cushioning materials are generally used for packing glass bottles. Pouches and fresh produce. There are various types of inserts and cushioning materials that are being used.

- **'Cell pack'** – Traditional partitioning method contribute to the stacking strength of the box.

- **'Paper honey comb'** – Can be adopted to different produce size and shape.

- **'Moulded pulp trays'** – Generally used for eggs and fruit and vegetables.

- **'Expanded polystyrene inserts'** – Can be produced in short runs at reasonable costs.

- **'Thermoformed PVC trays'** – Generally used for packaging produce in single layers only.

- **'Paper wool or wood wool'** – In combination with paper tissue, gives good protection if tightly packed.

- **'Plastic foam net'** – Generally used for glass bottles and large size fruits.

Barrels and Drums

Metal and wooden barrels are commonly in use. The metal barrels include steel and aluminium. Aluminium barrels are used for storing beer. Wooden barrels are made of staves bound together with hoops and may be 'tight' or 'slack'. The tight ones are used for storing heavy solids. semisolids and liquids. The wooden barrels are also used for storage and ageing of alcoholic liquors.

A drum is a cylindrical shipping container differing from barrels in having straight sides and flat or bumped ends designed for storage and shipments as an unsupported outer package that may be shipped without boxing or crating. Drums can be either metal drums (usually from Aluminium or Steel) fibre drums, ply wood drums and plastic drums. Metal drums are single wall, with either double head, partial opening, with convex or flat head or flat full removable head construction. The capacity usually ranges from 12-110 gallons. The inner surfaces of the metal drums are coated with lacquers. The commercially used lacquers are oleoresinous types. phenolic resins, vinyls, and epoxy resins.

Fibre drums are made by fibreboard of plies not less than 0.3 mm thick. The capacity of these drums varies between 0.5 to 100 gallons. The advantages of fibre drums are they are not returnable and has good stackability, low tare weight and easy opening and closing features. Printing can improve their appearance. Care should be taken not to expose these drums at high relative humidities.

The basic types of fibre drums are;

- Plain drums – No moisture proofness.
- Liquid tight drums – has rubber or plastic gaskets.
- Water vapour proof drums – Inside laminated with asphalt paper or polyethylene.
- Lined and coated drums – Prevents direct contact between content and fibreboard.

Fibre drums are generally used for shipping semisolids having a minimum viscosity of 5000 cps. It is also used for liquid insecticides fruit juices and other food stuffs. Plywood drums are made of 3 ply veneer which laps and joined with staples. The ply wood drums are primarily used to pack dry products and have an excellent weight to strength ratio.

The polyethylene drums are rigid and self supporting. They are available between 5-55 gallons capacity. The advantages of these drums are its flexibility, non toxicity, light weight, durability, high chemical resistance. The polythene drums have good resistance to breakage.

Sacks

Sacks are generally made from flexible low cost materials like jute, textiles, papers and plastics. Paper sacks are made of two or more plies of sack krafts, which is pure sulphate paper having a substance of 70 gsm or more.

Plastic sacks are generally made from polyvinyl chloride, polyethylene and polypropylene. The advantages of plastic sacks are, it weighs only 2/3 of multiwall paper sack and has better weather and impact resistance. These sacks are made by extrusion and blowing. The closures are made by sticking or heat sealing.

Sacks made from a combination of plastic and jute are also commercially available. Fresh fruit and vegetables are generally packed in sacks for transportation from harvesting fields to packing houses and/or retail markets. Sacks do not provide support for the product against superimposed loads and also offers less resistance to impact loads. Possibilities of sifting and spilling are common.

Bag-in-Box

In this system, the bag is supported on the outside by a rigid container made of paper board or corrugated board carton. It is generally used to fill a variety of liquid and dry products like tea, instant coffee, milk foods, baby foods, glucose powder, biscuits, spices, aseptic and non-aseptic fruit juices, edible oil, ghee etc. This system is tamperproof and offers cost effectiveness. Depending on the product, wide range of plastic films, laminates, coextruded barrier films, metallised film and aluminium foil can be used for the inner construction.

There are two methods of producing bag-in-box packages:

- Lined carton system,
- Coated and laminated carton system.

In the case of lined carton system, the inner liner is made from a suitable laminate such as LDPE/Paper/HDPE, paper/foil/LDPE and polyester to give the required shelf-life protection to the product. The outer carton is made of duplex board for protection against damages.

The second method combines the carton forming/gluing operation with a lining feed mechanism. Products considered for bag-in-box packaging should be tested for compatibility with the package and performance under handling shipping conditions.

Palletisation

A pallet is a platform made to hold one or more boxes, bags, cartons etc. in a group. The pallet is one of the simplest single devices for material handling. The other advantages of palletisation are:

- Reduced labeling requirements.
- Better utilization of storage space because of higher stacking strength.
- A reduction in mechanical strains and damages.
- A reduction of the total distribution time.
- A better maintenance of produce quality.

A pallet can be made of wood, corrugated and honey comb paperboard, plastic, reinforced plastic or metal. The choice is based on the service conditions, such as weight of load, climatic environment, durability requirement, local availability and costs.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Define primary, secondary and tertiary packaging.

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2. Describe the suitability of plastics for packaging of foods.

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2. Describe the suitability of wooden containers and CFB box for packaging and transportation of foods.

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8.8 QUALITY TESTING OF PACKAGES AND PACKAGING MATERIALS

An essential part of any packaging programme is the testing and evaluation of the complete packaged unit, as well as the various components. It is good economics to determine the optimum design in the beginning to maintain uniform performance throughout the life of the package. A good test programme will indicate the results to be expected in the field and it will yield dividends far in excess of its original cost and good management demands an objective evaluation of every step in the packaging operation.

To predict the performance of a package, there is a necessity to use a wide array of test procedures in package performance analysis with the following aspects:

- Identification of various materials used in packaging.
- Suitability of the materials for the intended use.
- Knowledge of materials properties both when used alone and when used in combination with other packaging materials.
- Ability to evaluate the material performance in the final package form in contact with packaged product.
- Determining the durability of materials through normal or even abnormal handling and abuse (including shipping).

8.8.1 What is Testing?

A test can generally be defined as an act of determining a given property or characteristics of a product (packaging material or package) by taking one or more measurements qualitatively or quantitatively according to prescribed procedure.

8.8.2 Why Testing?

Tests on packaging materials and packages are performed mainly for the following purposes:

- Comparison with competitive material to compare the offers.
- Current checks over the uniformity of new supplies of packaging materials, i.e., to check for change in quality if any from batch to batch.
- Quality checks during the production of packaging materials or packaged commodities.
- Evaluation of the suitability of packaging materials for certain factors like protection against mechanical or climatic hazards.

8.8.3 Steps in Test Methods

- Scope: The purpose and limitations of the methods are to be elaborated to avoid ambiguity.
- Significance: Relevance, the test has with respect to actual or intended performance.
- Terminology: The technical terms and abbreviations used should be fully defined or explained when they are not in common use
- Apparatus: All the various equipments necessary should be fully described in all the details, including dimensions range and accuracies etc.
- Materials: All reagents etc. are to be given in detail.
- Sampling: Enough attention has to be paid to proper sampling since a test can be only as informative as the sample permits

- Test specimen: The test sample consists of a minimum number of specimens and these specimens are to be prepared as required for the measurement of property and to suit the requirement. Preparation of the specimens is very important for the reliability of the test results.

- Conditioning: Time, temperature and relative humidity, to which the specimen are to be preconditioned and also conditions during testing.

- Test procedure: Method of actual measurement when there are more than one procedure. The procedure to be followed is described in detail.

- Method of evaluation: This gives the method (calculations) employed to arrive at the test property from the observations (readings) taken.

- Report: This tells how the results are to be reported and includes the method of presentation, its form (tables, graphs, diagrams etc.). Some times the precision of the test is also included in the report.

8.8.4 Package Functions and Characteristics

Mostly the evaluation of packaging materials is based on package functions and the characteristics of package.

Product Protection

1. Storage life of food products: Mainly depends upon the barrier properties of the packaging materials for:

   - Humidity: Water vapour transmission.
   - Gases: Oxygen/Carbon dioxide/Nitrogen/Sulphur dioxide.
   - Aroma: Specific organic vapour and transmission rate.

2. Product damage and integrity:

   In terms of resistance to stresses in distribution.

   - Impact resistance.
   - Dart impact and Spencers impact value for the film.
   - Compression resistance for finished packages.

   In terms of resistance to bursting:

   - Bursting strength.

   In terms of resistance to repeated stresses as in vibrations:

   - Gelboflex crack resistance for films/laminates/coextruded films.

3. Product packaging compatibility:

   Chemical resistance:

   - Grease resistance.
   - Tainting.
   - Migration of constituents from packaging materials into foods.

4. Pilferage and adulteration:

   Good closure and joints required.

   - Heat seal in plastic pouches.

Machinability

1. Easy sliding on machine:
   - Reduced friction.
   - Slip of packaging material surface (kinetic coefficient of friction).
2. Resistance to stresses in packaging operations:
   - Tensile strength and elongation.
   - Resistance to tear propagation.
   - Heat seal range and hot tack

Consumer and Marketing Functions

1. Ease of opening and reclosures:
   - For flexible pouches a 'V' – notch to start tear (good with foil laminates and cellophanes) may not be suitable for polythene and Nylon films.
   - Fold retention for closures of laminate pouches
2. Ease of dispensing:
   - Wide mouth for solids and pasty foods.
   - Clean squeeze out from flexible pouches (Non stickiness to the package wall).
   - Ease of disposal – problems for the future, particularly for non-recyclable multilayer plastic packs.

8.8.5 General Common Tests for Films, Foils, Laminates and Paper and Paper Board

Thickness

Thickness is the perpendicular distance between the two outer surfaces of the material and is normally expressed in units of length. Many physical properties of packaging materials are dependent upon the thickness, e.g. WVTR and GTR of films are inversely proportional to thickness and decreases with increase in thickness. For paper board, thickness is reported in points or in mm. (1 point = 1/1000") for papers, it is in mm or inches. For films, thickness is reported in micron, mils. or in gauges (25 micron (μm) = 1 mil = 1/1000" = 100 gauge = 0.025 mm.

The Basis Weight (for paper and paper boards)

The basis weight is the average weight of an arbitrarily selected area of the paper (weight per unit area i.e. gms/ sq.metre or lbs/1000 sq.ft for paper boards). As the packaging papers are sold and purchased only in terms of weight the basis weight assumes special significance. Most of the physical properties such as burst strength; thickness and bulk are evaluated and specified in accordance with the particular basis weight involved.

Tensile Strength Test

The tensile strength of paper is defined as the force applied parallel to the plane of the specimen of specified width and length under specified condition of loading (K gms/15 mm or lbs/inch width). The test indicates the durability and serviceability of papers in many packaging operations such as wrapping, bagging. printing etc. Usually tensile strength is more in machine direction than in transverse direction and extension is less in machine direction than in transverse direction. Plastic films are normally tested at higher speeds because of higher extensibility. The stress strain curve helps in locating yield point and knowing the yield strength etc.

The Bursting Strength Test

This test measures the ability of a paper or paper board to withstand pneumatic or hydraulic pressure build up. For films, foils, laminates and papers the pneumatic type test is used. Heavy papers and paper boards are tested on hydraulic type of testers (lbs/sq.in or kg/sq. cm). The test gives a sort of combined tear and tensile properties. In many cases it serves as good index of the quality of fabrication of packaging materials. Another Associated property is Burst factor. The burst factor = Bursting strength (in gm/sq.cm)/Basis weight (in gm/sq.mt).

Water Vapour Transmission Rate

The water vapour transmission rate (WVTR) is measured as the quantity of water vapour in gms that will permeate from one side to the other side of the film of an area of one square metre in 24 hours, when the relative humidity difference between the two sides is maintained at 90% gradient at 37.8°C. The property is important to estimate the efficiency of the packaging material or a package for resistance to the flow of water vapour and is helpful in considering the selection of barrier materials for hygroscopic foods.

Gas Transmission Rate

The gas transmission rate (GTR) is normally determined by measuring the change in volume at constant pressure (atmospheric), or the change in pressure at constant volume and the quantity of gas flowing across the film is compiled as volume at NTP.

$$\text{GTR} = \frac{\text{V.(76)x24}}{\text{At(P1} - \text{P2)}} \text{ cc/ m}^2\text{/ 24 hrs.atm} \qquad (8.1)$$

where ‘V’ is the volume (at NTP) of gas transmission through 'A' sq. metres of the test material in time 'f, when the average pressure difference between the two sides is maintained at (P1-P2) cm of Hg. The temperature of the test can be changed as per the requirement. GTR is an important property to estimate the efficiency of the packaging material or a package for resistance to the flow of gases and helps in selection of barrier materials for oxygen sensitive foods.

Grease Resistance

Grease resistance is measured by exposing one side of the test specimen creased or uncreased to a grease containing red dye. The time required for the red stain to show on the unexposed side is taken as a measure of this property. For plastic films, the test can be performed directly in pouches using groundnut oil coloured with red sudan dye.

Tearing Resistance for Papers

The papers are tested for their tearing resistance properties in two ways:

i) Internal tearing: The energy required to propagate an initial tear is measured (More followed in practice).
ii) Edge tearing: The energy required to initiate a tear is measured. The test is done on both the directions of paper. The work done in tearing is measured by the loss in the potential energy of the pendulum of the instrument. Tear Factor: is a term similar to Burst Factor, one finds in use.

$$\text{Tear factor} = \frac{\text{Tearing resistance in gms.}}{\text{Basis weight in GSM}} \times 100 \qquad (8.2)$$

Impact Tests for Plastics

These tests are designed to measure the ability of the films to withstand fracture by shock. The test is a measure of toughness of the material. It is a combination of deformation and breaking properties.

The Abrasion Resistance

This test is designed to measure the ability to withstand surface wear and rubbing. It is a measure of some mechanical properties like hard resillience. The procedure consists in abrading the sample with a wheel of standard abradent for a definite number of revolutions and finding the weight loss of the sample.

Heat Seal Strength

The test is used for heat sealable plastic packaging materials. The heat seal strength may be expressed as percentage of the tensile strength of the base material (gm/ cm width). The strength of heat seal depends upon temperature, dwell time, pressure and the type of heat sealing surfaces and each material has optimum values under these conditions.

Environmental Stress Cracking

The purpose of the test is to study the influence of some reagents like soaps, wetting agents, oils or detergents on plastics, determined by exposing the specimens for a specific time to those environments and observing the cracks. The test report consists of the percentage of failures.

Identification of Plastic Films

Different types of plastics used in packaging differ in their properties. It becomes necessary to identify them for their proper selection. Though there is no systematic method for identifying packaging films, based on some characteristics of various films, such as appearance, odour, feel and drape, they can be identified by a few simple tests like specific gravity, solubility, burning and copper wire test etc. For laminates and coextruded films, it is difficult to identify by such simple tests. Nowadays IR spectroscopy and NMR are used to identify qualitatively as well as quantitatively.

Specific Tests

Apart from these common tests, there are some specific tests for different packaging materials which are enlisted in various standards developed by the Bureau of Indian Standards and other organizations.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Define testing and enlist three reasons for testing of packages.

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2. Describe two tests each for the following packaging materials.

i) Paper and foils.
ii) Plastics.

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8.9 STANDARDS FOR SAFE PACKAGING

The packaging laws and regulations affecting food products are mainly covered under:

- The Standards of Weights and Measures Act, 1976, and the Standards of Weights and Measures (Packaged Commodities) Rules, 1977 (SWMA).
- The Prevention of Food Adulteration Act, 1954, and the Prevention of Food Adulteration Rules, 1955 (PFA).
- The Fruit Products Order, 1955 (FPO)
- The Agmark Rules

8.10 DISPOSAL OF PACKAGING MATERIALS

Indiscriminate use of different packaging materials for packaging of food products has caused a serious problem of pollution and ecological imbalance due to the problem of their disposal. Packaging waste contributes in great proportion to the increase in the volume of waste and to the saturation of landfills. The packaging sector, especially the plastics industry, is currently under some attack from the environmental point of view due to problems in waste disposal, pollution by litter and waste of resources.

At present, the following different principal methods are used to control solid waste disposal.

i) Land in-fill
ii) Incineration
iii) Composting
iv) Direct constructional use (unsorted) (v) Reuse (sorted)
v) Pyrolysis
vi) Chemical treatment

In the case of land in-fill method, the waste is reduced in particle size and then deposited in a special location, which may be excavated and covered with a minimum level. The process is hygienic and can reclaim wasteland. Incineration comprises the burning of waste till all combustible matter is fully oxidized. Composting involves biodegradation leading to a bland product, which is useful in agriculture. In direct constructional use, the waste is treated to compact, compressed with binders like bitumen and the resulting blocks are used for construction of roads, artificial islands, causeways, airfields, etc.

Packaging materials like metal, paper and glass can be segregated and reused or recycled. Pyrolysis is a method of heating material in the absence or presence of a limited amount of oxygen and the components can be separated for reuse. The chemical treatment is oriented towards a specific component of waste like hydrolysis of polyurethanes in scrap automobiles and degradation of paper to sugars or alcohols.

When the product is removed from the packed container, it becomes litter, which is harmful, polluting and expensive and this has to be disposed off quickly.

8.10.1 Recycling of Packaging Materials

Recycling of packaging materials play a very important role in saving the raw material, energy and to minimize the environmental pollution.

Recycling of tin-plate is a cumbersome process, since the lacquers / lithography and tin has to be separated from the base steel. Then the base steel can be sent to the steel-producing plant for remelting to produce fresh steel plate for reuse. The separation of steel from tin in two-piece cans and lids is easier and more economical. Similarly, chromium can be separated from the tin-free steel and the base steel can be reused for production of fresh base plate.

By recycling aluminium, more than 90 per cent of the energy can be saved by melting and reprocessing the metal. It is also claimed that the quality of recycled aluminium is better. About 50-60 per cent of the aluminium cans are recycled.

With respect to plastic packaging materials, PET can be reprocessed and used for stuffings, plates, piping, fibres, etc. Used PET bottles are not suitable for production of fresh PET bottles. Plastic-wastes are also used for recovery of energy by incineration.

8.10.2 Biodegradable Plastics

Plastics used in food packaging at present are non-biodegradable. The overflowing landfills cannot absorb the large quantity of plastic trash created in many countries. To reduce the waste, the best solution is a combination of biodegradable plastics, plastics recycling and composting. Biodegradable plastics are biodisintegratable plastics, which disintegrate into polymer chains and break down into water and carbon dioxide.

The first generation biodegradable plastics are made of polymers containing about 6 per cent starch (normally, corn starch), which biodegrades and a pro-oxidant, which enhances the reaction of the polymer with oxygen in the air. New biodegradable plastics contains up to 97 per cent starch.

Biodegradable plastics have the same strength and flexibility as commonly used petroleum-based plastics and can be melted, moulded and shaped as required. However, they are not suitable for applications requiring high-temperature resistance or impact. The same production techniques like injection moulding, extrusion blow-moulding, melt casting or spinning used for plastic-based plastics can be used without retooling the manufacturing plant. Biodegradable plastics are viable alternatives and are gradually becoming popular commercially.

Other than biodegradable plastics, chemical and photodegradable plastics have also been developed. They are chemical plastic, for which a natural catalyst like metal salt is added and the photodegradable plastic for which a light-sensitive chemical is added to or sprayed on the plastic to make it disintegrate in ultraviolet light.

8.11 SPECIAL PACKAGING

Other than the traditional packaging materials, there are some special ones, which can be selectively used for packaging of foods. Some of them are discussed in the following paragraphs:

8.11.1 Edible Films

Natural edible films extend shelf life, although for shortest time periods than synthetic non-edible packaging materials. Examples of edible films include casings, such as in sausage, and edible waxes, such as those applied to fruits and vegetables, the waxes function to improve or maintain appearance, prevent mold, and contain moisture while still allowing respiration. Food may be coated with a thin layer of polysaccharides such as cellulose, pectin, starch and vegetable gums, or proteins, such as casein and gelatin. Cut dried, fruit pieces are often sprayed with an edible film prior to their inclusion into items such as breakfast cereal.

8.11.2 Foil

These may be used in snack bags (chips, etc.) or as a laminate in aseptic packaging. It is used as a wrapping for dry, refrigerator, or freezer storage. It provides a moisture-proof and vapour-proof barrier,

8.11.3 Laminates

These are multilayers of foil, paper, or plastics which may be utilized selectively according to the specific food packaging need, In combination, the various laminates may provide more strength and barrier protection than the individual laminate material. Laminates provide barriers useful in controlling O_2, water vapor, and light transmission, and they provide good burst strength. The laminates may resist pinholes and flex cracking. Retort pouches are examples or laminates used in packaging and contain polyester film, aluminum foil, and polypropylene.

8.11.4 Vacuum Packaging

Vacuum packaging modifies the atmosphere surrounding the food by removing oxygen, and it extends shelf life. Vacuum-packaging machines are available for small-, medium-, or large-scale production capacity and may be used to successfully package a variety of food sizes and forms such as small cheese blocks, large primal cuts of meat, or liquids. The procedure used for vacuum packaging is to place the food in a flexible-film, barrier pouch, and put it inside a vacuum-packaging chamber, where oxygen is removed. This creates a skintight package wall and protects against the entry of escape of gases such as air and CO_2, or water vapor. It assures inhibition of microbial growth, which would alter microbial and organoleptic properties such as appearance and odor. Water weight loss and freezer burn are also inhibited with this packaging method.

8.11.5 Modified Atmosphere Packaging (Map) Or Gas Flush Packaging

Modified atmosphere packaging modifies the internal package atmosphere of food. It is primarily applied to fresh or minimally processed foods that are still undergoing respiration, and it is used for the packaging of baked goods, coffees and teas, dairy products, dry and dehydrated foods, lunch kits, and processed meats in order to keep the meat pigment looking desirable. It is also used for nuts and snack food applications. MAP is one of the most widely used packaging technologies.

Modified atmosphere packaging contains the food under a gaseous environment that differs from air, in order to control normal product respiration (ethylene, CO_2, water vapor, and O_2) and growth of aerobic microorganisms. Nitrogen gas, which is odorless, tasteless, colorless, nontoxic, and nonflammable, is introduced into the food package after all atmosphere has been removed from the pouch and vacuum chamber and just prior to hermetic sealing of the package. This modification offers protection from spoilage, oxidation, dehydration, weight loss and freezer burn, and extends shelf life.

Unlike vacuum packaging, the film used for MAP remains loose-fitting, This avoids the crushing effects of skintight vacuum packaging, When used in combination with aseptic packaging, which reduces the microbial load, MAP becomes a more effective technology, Most new and minimally processed foods use MAP in combination with aseptic technology and reduced temperature.

8.11.6 Controlled Atmosphere Packaging

Both controlled atmosphere (CA) in storage environments and controlled atmosphere packaging (CAP) permit controlled oxygen and carbon dioxide exchange. Today, CAP containers control O_2, CO_2, water vapor, and ethylene concentration and, worldwide distribution of produce depends on CAP for high-quality food.

Clostridium botulinum is an anaerobic bacteria that grows in the absence of available oxygen. Therefore, it may grow in anaerobic packaging environments. To retard its growth in CAP food products, foods must have short storage times and be held at cold temperatures. Control of water activity (Aw) and salt is also necessary to prevent growth as sodium competes with the bacteria for water absorption

8.11.7 Active Packaging Technologies

Typically, packaging serves in a passive role by protecting food products from the external environment. It provides a physical barrier to external spoilage, contamination, and physical abuse in storage and distribution. Today, packaging more actively contributes to the product development, controls maturation and ripening, helps in achieving the proper color development in meats, and extends shelf life. It plays an active role in protecting foods. Examples of active packaging technologies are listed in the following:

Active packaging for fresh and minimally processed foods provide the following:

- Edible moisture or oxygen barrier (to control loss of moisture and enzymatic oxidative browning in fresh cut fruits and vegetables and to provide controlled permeability rates matched to the respiration rate of the fruit).
- Edible antimicrobial (biocidal) polymer films and coatings (which release controlled amounts of chlorine dioxide into the food, depending on temperature and humidity; or destroy E. coli 0157:H7 in meats, and prevent mold growth in fruits).
- Films that are scavengers of off-odours.
- Oxygen scavengers for low oxygen packaging.

Active packaging for processed foods provides the following

- Edible moisture barrier.
- O_2, CO_2, and odour scavenger.

Other active packaging technologies include the following:

- Microwave doneness integrators (indicators).
- Microwave susceptor films to allow browning and crispness (french fries, baked products, popcorn).
- Steam release films.
- Time-temperature indicators (TTI) which are unable to reverse their colour when the product has been subject to time-temperature abuse for frozen products.

8.11.8 Aseptic Packaging

In order to destroy any *Cl. botulinum* spores and extend the shelf life of low-acid foods, *aseptic packaging* may be utilized. Independent sterilization of both the foods and packaging material, with assembly under sterile environmental conditions, is the rule for aseptic packaging.

The container is filled with a sterile (no pathogens or spores) or commercially sterile (no pathogens, but some spores) liquid food product, and sealed in a closed, sterile chamber. Once packed, the product requires no refrigeration. Liquids such as creamers, milk, or juices may be packed in this manner. Triple or multiple packs of flavoured milk and juice, with attached straws, are available on grocery shelves. The market leaders of aseptic packages have introduced easy-open, easy-pour features into their canons. The plastic devices are injection moulded and adhere to the package tops.

8.11.9 Flexible Packaging

It is available for packaging use in the foodservice industry and is finding more applications at the retail level, including packaging for bagged cereals and sliced deli meat. Non-rigid packaging containers such as stand-up pouches or tubes and zippered bags are examples of flexible packaging used for peanuts, peanut butter, or produce such as fresh-cut lettuce and peeled baby carrots. (The packaging must also be resealable to meet consumer demands and may have zipper handles or spouts with screw-off tops.)

Flexible packaging is adequate for the plethora of low-fat/no-fat food products such as salty snack foods that are available in the marketplace. It keeps these products fresh by providing flavour and aroma barriers, which keep outside doors out and flavours in. It is used for fresh fruits and vegetables and matches respiration rate as closely as possible.

Manufacturers are offering more food products in flexible packaging and find that "cost savings and environmental concerns are two of the driving forces behind the switch to flexible packaging". "Faster, better, stronger, cheaper… the packaging industry continually tries to improve the process. Nowhere is this more apparent than in flexible packaging".

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.
c) Use separate sheets where no space is provided.

1. Enlist three standards for safe packaging of foods.

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2. Enlist the principal methods used to control solid waste disposal.

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3. Write short notes on the following:

i) Edible films	ii) Vacuum packaging
ii) Modified atmosphere packaging	iv) Controlled atmosphere packaging
v) Active packaging	vi) Flexible packaging

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8.12 LET US SUM UP

After studying the contents of this unit, you can appreciate that there are several options for transportation and packaging of food materials. Depending upon the location and the commodity, a rigid combinations of mode of transportation and packaging with minimum losses and at least cost.

While manual and animal drawn carts have their relevance for small distances, motorized transport is required to haul the food material over long distances. The tractor, truck, rail, sea and air transport modes have their useful mass based on the perishability, urgency, cost and benefit attributes.

The role of packaging is to facilitate handling and marketing and to ensure the minimum spoilage during storage, handling and transport. The packaging also has a criterion of consumer appeal. Besides food quality, the issue of food and environmental safety have also become important. The disposal of used packaging material so as not to cause pollution needs to be given due considerations.

8.13 KEY WORDS

Transport	:	It refers to the transfer of material from one place to another be it the transport of raw materials to the processing industry or the finished product from the industry to the market place.
Transmission rate of packages	:	It refers to the transfer of a particular component like water vapour, oxygen, etc. across the packaging material per unit area per unit time.
MAP	:	Modified atmosphere packaging contains the food under a gaseous environment that differs from air, in order to control normal product respiration (ethylene, CO_2, water vapour, and O_2) and growth of aerobic microorganisms.
CAP	:	Controlled atmosphere packaging (CAP) permit controlled oxygen and carbon dioxide exchange.
Active packaging	:	Packaging more actively contributes to the product development, controls maturation and ripening, helps in achieving the proper colour development in meats, and extends shelf life. It plays an active role in protecting foods.
Vacuum packaging	:	Vacuum packaging modifies the atmosphere surrounding the food by removing oxygen, and it extends shelf life.
Aseptic packaging	:	It is packaging of the food material in a sterile environment.
Biodegradable Plastics	:	Biodegradable plastics are biodisintegratable plastics, which disintegrate into polymer chains and break down into water and carbon dioxide.
Transportation cost	:	Involves all costs involved and each must be taken care to optimize profits.
CFB	:	The corrugated fibreboard is made of paperboard liners and corrugating medium. The structure of corrugated fibreboard consists of a fluting medium running in a sinusoidal wave form between the two liners, thus separate the liners by a distance to obtain good stiffness.
Bag-in-box	:	In this system, the bag is supported on the outside by a rigid container made of paper board or corrugated board carton.
Palletization	:	A pallet is a platform made to hold one or more boxes, bags, cartons etc. in a group.

8.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Appropriate packaging and transportation is one of these measures applied at all stages between the grower and the consumer in order to reduce wastage, improve food security and generate income and profit. When properly applied it can have a dramatic effect, towards reduction of losses and ensuring quality product for the customer. Appropriate packaging and transportation ranges from the proper use of containers in which to transport produce to local markets, through to sophisticated systems that can extend the shelf-life of a processed foodstuff for a year or more.

2. i) Suitability

   - Tran-shipment necessary.
   - Pilferage is a major problem.
   - Proper handling instructions essential.
   - Packages can be sent on railways risk.
   - Packages are to conform to rules and regulations of the Railways.
   - Door to door delivery possible only by container service.
   - No problem for inter-state transport.
   - Less interruption of journey even in rainy season.

   Hazards:

   - Stacking height upto 8 feet.
   - Vibration due to rail joints and track conditions.
   - Shunting shock.
   - Very high temperature (upto 70°C) in steel wagons in summer.

   ii) Suitability

   - High freight charges and hence lighter packages to be used.
   - Limitations on size & weight of packages.
   - Less journey time.
   - Better handling.
   - No cooling facility available.

   Hazards:

   - High frequency vibration due to engine.
   - Low temperature and pressure when flying at high altitudes.

3. Three factors that cause deterioration of foods during storage are:

   - mechanical forces (impact, vibration, compression or abrasion),
   - climatic influences that cause physical or chemical changes (UV light, moisture, oxygen, temperature changes),
   - contamination (by micro-organisms, insects or soils).

4. Four packaging functions are as follows:

   - Preserving against spoilage of colour, flavour, odour, texture, and other food qualities.
   - Controlling absorption and losses of O_2 and water vapour.

- Offering adequate storage before use-such as stockable, resealable, pourable.
- Preventing/indicating tampering with contents by tamper-evident labels.

Check Your Progress Exercise 2

1. A ***primary*** container is the bottle, can, drink box, and so forth that contains food. It is a direct-food-contact surface. Several primary containers are held together in ***secondary*** containers, such as corrugated fiberboard boxes (commonly, but not correctly, referred to as cardboard), and do not have direct food contact. In turn, several secondary containers are bundled into ***tertiary*** containers such as corrugated boxes or overwraps that prepare the food product for distribution or palletizing.

2. a) Different types of plastics available for food packaging.
   b) Their suitability for packaging of food materials.
   c) Their relative advantages and disadvantages.

3. a) Describe wooden containers and CFB box.
   b) The type of foods that can be packed using wooden containers and CFB box.
   c) Their advantages and disadvantages if any, over other packaging materials.

Check Your Progress Exercise 3

1. A test can generally be defined as an act of determining a given property or characteristics of a product (packaging material or package) by taking one or more measurements qualitatively or quantitatively according to prescribed procedure. Three reasons for testing of packages include the following:

   - Comparison with competitive material to compare the offers.
   - Current checks over the uniformity of new supplies of packaging materials, i.e., to check for change in quality if any from batch to batch.
   - Quality checks during the production of packaging materials or packaged commodities.

2. i) Tensile strength and tearing strength tests

   ii) Water vapour transission rate and bursting strength tests

Check Your Progress Exercise 4

1. The three packaging laws and regulations affecting food products are:

   - The Standards of Weights and Measures Act, 1976, and the Standards of Weights and Measures (Packaged Commodities) Rules, 1977 (SWMA).
   - The Prevention of Food Adulteration Act, 1954, and the Prevention of Food Adulteration Rules, 1955 (PFA).
   - The Fruit Products Order, 1955 (FPO)

2. The principal methods used to control solid waste disposal are:

   i) Land in-fill.
   ii) Incineration.
   iii) Composting.
   iv) Direct constructional use (unsorted).
   v) Reuse (sorted).
   vi) Pyrolysis.
   vii) Chemical treatment.

3. In all the short notes the following points needs to be covered:

   i) The definition.
   ii) Use and principle.
   iii) Foods suitable for the method.
   iv) Advantages and disadvantages of the method.

8.15 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

3. Vaclavik, C.A. and Christian, E.W. (1999) Essentials of Food Science. Aspen Publisher, Inc., Maryland, USA.

UNIT 9 JUICE AND BEVERAGES

Structure

9.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- prepare various fruit beverages;
- learn principles of various preservation techniques;
- know equipment used in the processing of fruit beverages;
- explain quality aspects and standards of product; and
- describe packaging requirements and types of packaging material.

9.1 INTRODUCTION

Fruit beverages are easily digestible, highly refreshing, thirst- quenching, appetizing and nutritionally far superior to synthetic and aerated drinks. The fruit beverage include natural and sweetened juices, squash, syrup, fruit juice concentrate and fruit juice powder.

In this unit we will study the various steps in the preparation of fruit beverages, and their preservation methods for extending their shelf life. Measures taken to improve the quality of the final product by Fruit Products Order (FPO) is also given in this unit. Apart from this, you will learn the importance of packaging and different packaging materials used in the processing industry.

9.2 FRUIT JUICE

The concept of fruit juices has gained immense consumer popularity. Fruit juices are products for direct consumption and are obtained by the extraction of cellular juice from fruit, this operation can be done by pressing or by diffusion. The fruit juice processing technology employed for different fruits and the various equipments required during different stages of processing has been covered here.

9.2.1 Preparation of Fruit Juice

Fruit juices must be prepared from sound, mature fruits only. Soft fruit varieties such as grapes, tomatoes and peaches should only be transported in clean boxes, which are free from mould and bits of rotten fruit. The flow chart for fruit juice production is given in Figure 9.1.

Fruits
↓
Receiving the material
↓
Washing
↓
Sorting
↓
Crushing/Grinding/Disintegration
↓
Enzyme treatment
↓
Extraction/ Expression
↓
Straining/Filtration
↓
Clarification (Optional)
↓
De-tartarisation (Optional)
↓
Preservation of fruit juice
↓
Filling in sterilized bottles
↓
Corking
↓
Pasteurization
↓
Labelling and Storage

Figure 9.1: Flow chart for fruit juice production

Washing: Fruit must be thoroughly washed. Generally, fruits are submitted to pre-washing before sorting and a washing step just after sorting. Washing can be done either by water or by dilute hydrochloric acid (1 part acid : 20 part water).

Sorting: Removal of partially or completely decayed fruit is the most important operation in the preparation of fruit for production of first quality fruit juices; sorting is carried out on moving inspection belts or sorting tables.

Crushing/Grinding/Disintegration: This is applied in different ways and depends on fruit types: Crushing for grapes and berries; Grinding for apples, pears; Disintegration for tomatoes, peaches, mangoes, apricots etc. This processing step will need specific equipments, which differs from one type of operation to another.

Enzyme treatment: The enzyme treatment of crushed fruit mass is applied to some fruits by adding 0.2-0.8% pectolitic enzymes at about 50° C for 30 minutes. This optional step has the following advantages: extraction yield will be improved, the juice colour is better fixed and taste of finished product is improved.

Expression/extraction*:* Generally juice is expressed from the crushed/disintegrated fruit pulp. During expression, juices should not be unnecessarily exposed to air as it will spoil the colour, taste and aroma and also reduce the vitamin content.

The equipments used for the juice extraction are screw type juice extractors, basket presses or fruit pulpers (shown in figure). All equipments used in the preparation of fruit juices and squashes should be rust and acid proof. Copper and iron vessels should be strictly avoided as these metals react with fruit acids and cause blackening of the product. Machines and equipments made of aluminium, stainless steel, etc can be used.

Straining/Filtration*:* The extracted juice contain some amount of suspended matter. The suspended matter consists of broken fruit tissue, seed, skin, gums, pectic substances and protein in colloidal suspension. These materials can be removed by straining through a thick cloth or sieve. Removal of all suspended matter improves the appearance but often results in disappearance of fruity character and flavour. The present practice is to let fruit juices and beverages retain a cloudy or pulpy appearance to some extend (Figure 9.2).

Clarification: It is the process of complete removal of all suspended material from the juice**.** This can be performed by many methods viz. centrifugation, enzyme treatment, settling, filtration, freezing(-18^{o}C), use of high temperature (nearly 82^{o}C) and low temperature(-2 to –3 ^{o}C). The chemical treatments like addition of gelatin, albumin, casein, or a mixture of tannin and gelatin are also used for the removal of suspended particles.

Centrifugation is carried out in centrifugal separators with a speed of 6000 to 6500 rpm. Enzyme clarifying is based on pectic substance hydrolysis; this will decrease the viscosity of juice and facilitate their filtration. The treatment is the addition of pectolitic enzyme preparations in a quantity of 0.5 to 2 g/l. This will last for 2 to 6 hours at room temperature, or less than 2 hours at 50° C, a temperature that must not be exceeded.

De-tartarisation is applied only to raisin juice and is aimed to eliminate potassium bi-tartrate from solution. This step can be performed by the addition of 1% calcium lactate or 0.4% calcium carbonate.

9.2.2 Preservation of Fruit Juices

Fruit juice is preserved to prevent the decay/spoilage and to extend the shelf life of the juice in a good condition for future use. This is generally done by the use of high temperature (pasteurization and flash pasteurization), use of low temperature (refrigeration and freezing), preservation with chemicals (sulphur dioxide and benzoic acid), drying, filtration, carbonation, and by using sugar. The methods used for the preservation are follows:

Pasteurization

Preservation by heat is the most common method. It is the process of heating fruit juice at boiling temperature or slightly below it for a sufficient length of time to kill the microorganisms that cause spoilage. The juice is hermetically sealed in containers before being pasteurized. Usually the fruit juices are pasteurized at about 85°C for 25 to 30 minutes according to the nature of the juice and size of the container.

Flash Pasteurization

In this method, fruit juice is heated for a short time at a temperature higher than the pasteurization temperature and held at that temperature for about a minute and then filled into containers which are sealed air tight under cover of steam to sterilize the seal and then, cooled. For the maintenance of the product quality, the rate of heat transfer in these pasteurizers are kept high. The heat transfer depends on the viscosity of the juice, specific heat of the juice and temperature difference. This method has many advantages viz., minimum loss of flavour, preservation of vitamins, economy of time and space, uniformity in body of juice, and minimum cooked flavour.

Preservation by Chemicals

Microbial spoilage of fruit beverages is also controlled by using chemical preservatives. The inhibitory action of preservative is due to their interfering with the mechanism of cell division, permeability of cell membrane and activity of enzymes. Pasteurized fruit beverages undergo spoilage once opened. To avoid this it is necessary to use chemical preservatives. Chemically preserved beverages can be kept for a fairly long time even after opening the seal of the bottle. The two important chemical preservatives permitted in our country by FPO are sulphur dioxide (including sulphites) and benzoic acid (include benzoates).

Sulfur dioxide: It is widely used throughout the world in the preservation of fruit juice and other beverages. It has good preserving action against bacteria, moulds and inhibits enzymes. In addition, it acts as an antioxidant and bleaching agent. It is generally used in the form of it’s salts such as sulphite, bisulphite and metabisulphite.

The advantages of using sulphur dioxide are:

1. It has better preserving action against bacterial fermentation
2. It helps to retain colour
3. It ensures better mixing and hence their preservation

4. It helps in preserving the surface layer of juices.
5. Excess amount can be removed by heating or by vacuum

The limitations of sulphur dioxide are:

1. It can't be used in some coloured juices like those of jamun, strawberry etc on account of its bleaching action.
2. It corrodes the tin containers.
3. Some consumers may be sensitive to sulphur dioxide.

Benzoic acid: It is only partially soluble in water and hence it's salt, namely sodium benzoate is used as preservative. Pure sodium benzoate is tasteless and odourless. The antibacterial action of benzoic acid is increased in the presence of CO_2 and acid. Benzoic acid is more effective against yeast than against moulds. The quantity of benzoic acid depends on the acidity of the products. In case of fruit juices with pH of 3.5-4, addition of 0.06% of sodium benzoate is recommended.

By Addition of Sugar

Syrups containing 66 % or more of sugar do not ferment. Sugar absorbs most of the available water with the result that there is very little water for the growth of microorganisms. This reduction in water will inhibit the multiplication of microorganisms and gradually they die out from the product.

By Freezing

Microbial growth and enzymatic reactions are retarded in juice stored at low temperatures. The lower the storage temperature the slower will be the rate of a chemical or enzyme reaction. Freezing is the process in which the temperature of a food is reduced below the freezing point, and a proportion of the water undergoes a change in state to form ice crystals. Under the usual condition of storage of frozen foods, microbial growth is prevented completely and the action of food enzymes greatly retarded. The best way of preserving pure fruit juice is by freezing. Properly frozen juice retains its freshness, colour and aroma for a long time. This method is particularly useful in case of juices whose flavour is adversely affected by heating. Preservation by freezing is carried out at about −30° C, after a preliminary de-aeration. Then storage is done at −15 to −20° C.

By Drying

Drying is the processes of removal of moisture to a pre determined level. You know that the growth of microorganisms is directly dependent upon the concentration of water present in the food. So a reduction in moisture will reduce the growth of microorganisms. Moisture can be removed by the application of heat. The details regarding the methods of drying are given in the Unit 4.

By Carbonation

It is the process of dissolving sufficient carbon dioxide in fruit juice so that the product when served gives off the gas as fine bubbles and has characteristic taste. Carbonation is done at a concentration of 1.5% CO_2 under a pressure of 7 kg/cm². Another advantage of carbonation is the removal of air from the fruit juice, which reduces the oxidation of ascorbic acid, prevents browning and microbial growth. High carbonation should be avoided as it usually destroys the delicate flavour of the juice. The keeping quality of carbonated fruit beverages is enhanced by adding about 0.005 % of sodium benzoate.

By Filtration

In this method, the juice is first clarified through ordinary filters and then passed through special filters. These special filters retain yeast and bacteria. Various types of germ-proof filters are used for this purpose. This requires elaborate precautions to ensure complete sterility in the bottled product.

By Irradiation

The irradiation process involves passing of fruit juice through a radiation field allowing the juice to absorb desired amount of radiation energy. The juice itself never comes in contact with radioactive material. The gamma radiations from the radioactive material will disinfest, sterilize and preserve the fruit juice. The dose required to provide stability is partly determined by the solid content of the juice. Generally irradiation lightens the colour of the juice. On storage, however, darkening occurres and stored irradiated apple juice shows little difference from the original colour. Flavour changes caused by the irradiation are less. The dose required to obtain stability may be reduced by heating the juice to a higher temperature (50^{o}C) prior to irradiation. In this way, a dose of 3 kilo Grey is adequate to secure stability at ambient temperature for more than a year.

9.2.3 Bottling

Bottles are thoroughly washed with hot water and drained before filling. A 1.5 to 2.5 cm head space is left during filling. They are then sealed either with crown corks (by crown corking machine) or with caps (by capping machine).A typical corking machine is shown in Figure 9.2.

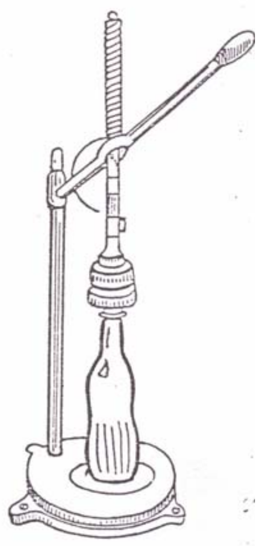


Figure 9.2: Crown corking machine

9.3 EQUIPMENTS FOR THE PRODUCTION OF JUICE AND PULPS

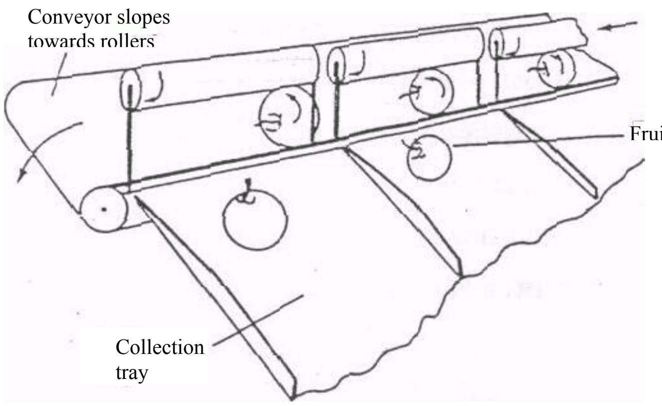
Different types of equipments are used in the juice processing plant, starting from equipments for washing, sorting, extracting to pasteurizers. While selecting an equipment the material of construction is very important. Glass-lined equipment, or equipment made of metals like stainless steel, monel metal, nickel, aluminium or bronze should be used because such equipment is not readily acted upon the fruit or vegetable juices. A unit of machinery made of different metals should also be avoided because is similar metals in the system or unit will lead to the setting up of small electrical couples and consequently corrosion will take place. Use of rubber in the equipments should be avoided as far as possible.

9.3.1 Washing Equipments

Different types of equipments are available for washing of fruits and vegetables. Tender fruits are usually washed with a fine overhead spray of water, while the fruits travel on a continuous woven wire belt. On small scale processing plants washing is carried out in cement or galvanized iron tanks.

9.3.2 Sorting Equipments

In large factories, a continuous broad belt, made of woven metal, is generally employed for sorting the fruits. In smaller factories, however, batch sorting will be sufficient. A schematic diagram of belt and roller sorter and screen sorter are shown in Figure 9.3a and 9.3b.



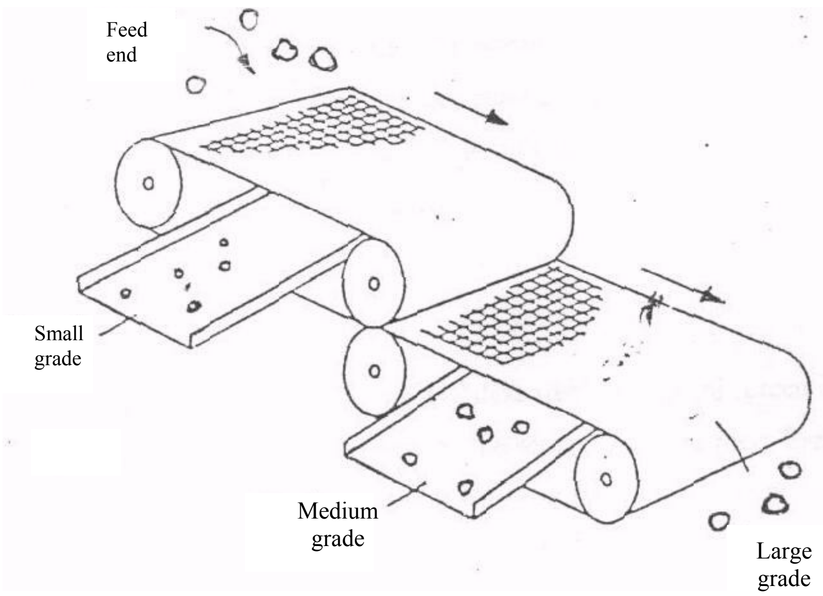
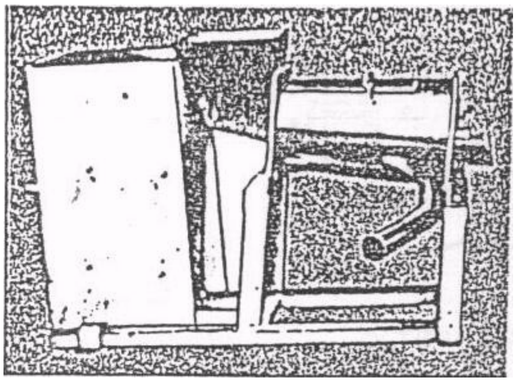


Figure 9.3: Sorting machines: a) Belt and roller sorter; b) Screen grader

9.3.3 Pulping/Grinding Equipments

There are two types of extractions. In the first case, the fruits are crushed and pressed continuously in one operation (Figure 9.4). In the second case, the fruits are crushed or cut into small pieces or comminuted in a mill, and these are subsequently pressed in a suitable press. Some of the crushing/ extraction equipments are discussed here.



Pulper

Figure 9.4: Fruit pulper

Hammer mills: These are devices to pulp/crush the whole fruit in preparation for extraction. Hammer mills consist of heavy stainless steel bars spinning from a common axis under a high speed of rotation. The fruit is disintegrated until it will pass out through a screen of specific size mounted in the bottom of the mill (Figure 9.5). The mash will be of finer particle size and the smaller particle size will allow greater yields in case of firm fruits. Softer fruit presses with more difficulty, and a larger particle size in the mash will enhance ease of pressing.

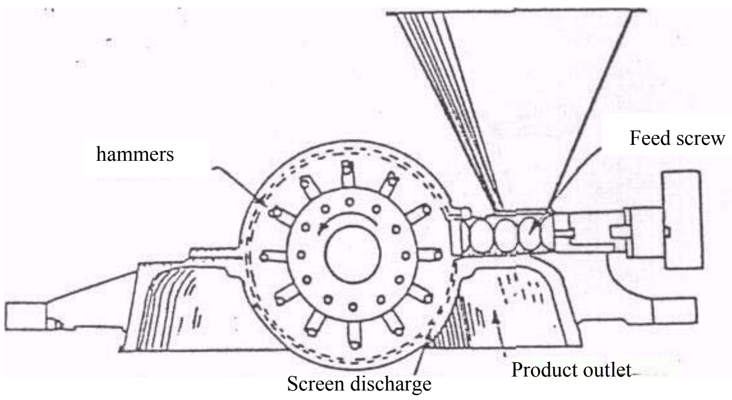


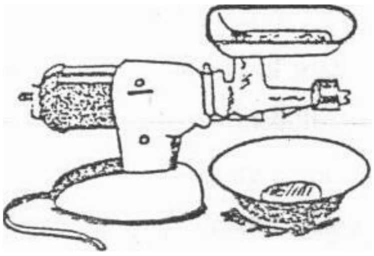
Figure 9.5: Sectional view of hammer mill

Grating mills: These offer an alternative method for disintegrating fruits. In grating mill, the fruit is drawn past fixed knifes mounted on a cylinder. Control of the grind is accomplished by adjusting the depth of the knifes and thus the size of cut from the fruit

Crusher: In grape juice processing, a stemmer/crusher removes residual stems, leaves, and petioles from the grapes and does the initial crush of the fruit after arrival at the plant. This unit is designed around a rotating drum perforated with holes of approximately 2.5 cm diameter. In the process of traversing the rotating drum, grapes are caught by the perforated drum and knocked from the stems. The individual grapes are broken open or crushed in the process and drop through the drum.

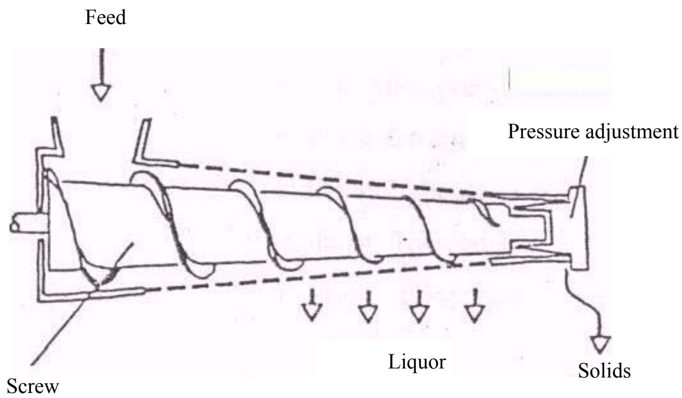
9.3.4 Screw Press

A typical screw press consists of a reinforced stainless steel cylindrical screen enclosing a large bore screw with narrow clearance between the screw and the screen. Breaker bars are located between the screw intervals in order to disrupt the compressing mash. Working principle of a typical screw extractor is shown in Figure 9.6a and Figure 9.6b. Back pressure is provided at the end of the chamber and is usually adjustable. The segments of the fruit are fed through a hopper at one end of a feeding screw, revolving inside the perforated screen. The juice flows out through the perforations and the pomace comes out through the other end. Capacities for screw press with a 30.5 cm and 41 cm diameter are 5,080 kg and 15,240 kg per hour.

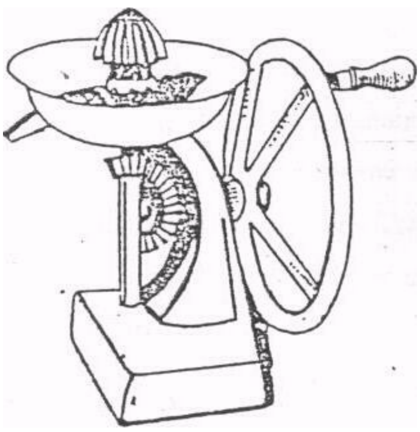


Screw Type Juice Extractor

(a)



(b)



Lime Juice Extractor

(c)

Figure 9.6: a) Screw extractor; b) Working principle of screw press; and c) Lime juice extractor

9.3.5 Basket Press

These are of various designs and capacities and are worked manually by hydraulic pressure. The manually operated press consists of a strong cylindrical basket which is made of wooden slates. It rests on a wooden or metallic base. There is strong screw at the top of this frame. The mash is folded in a strong cloth and placed inside the basket. By turning the screw by hand or with a hydraulic pump, the juice is pressed out. A schematic diagram of basket press shown in Figure 9.7.

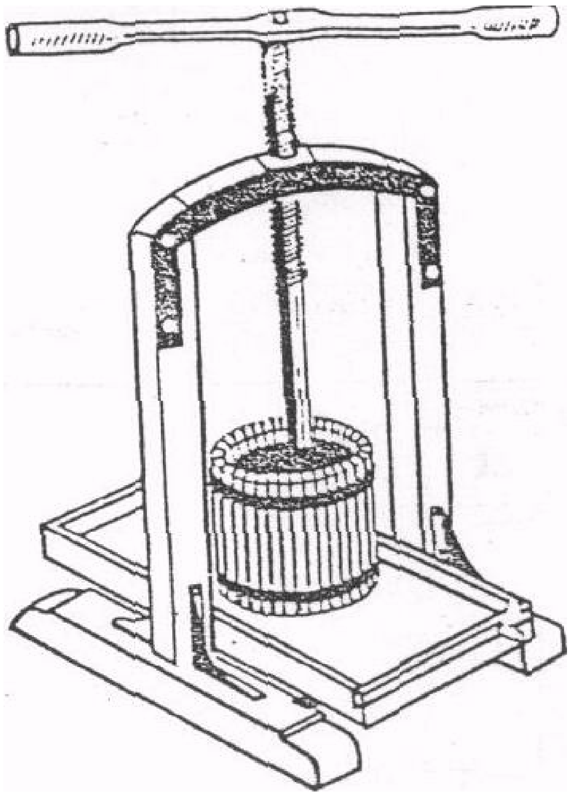


Figure 9.7: A typical basket press

9.3.6 Rack and Frame Hydraulic Press

The hydraulic rack and frame press is a very common press system found in small juice operations. It was the primary method of fruit juice pressing operations for many years. Heavy cotton or nylon cloths are filled with a set amount of mash and then folded to produce what is called a cheese. The individual cheese is stacked and separated by a wooden, stainless steel, or plastic spacer platen. The combined stack is then compressed using a hydraulic ram, during which the juice is expressed. A typical hydraulic juice press is shown in Figure 9.8.

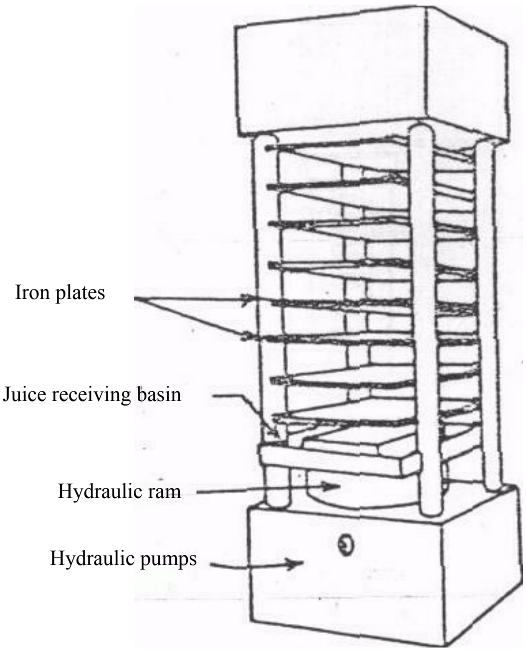


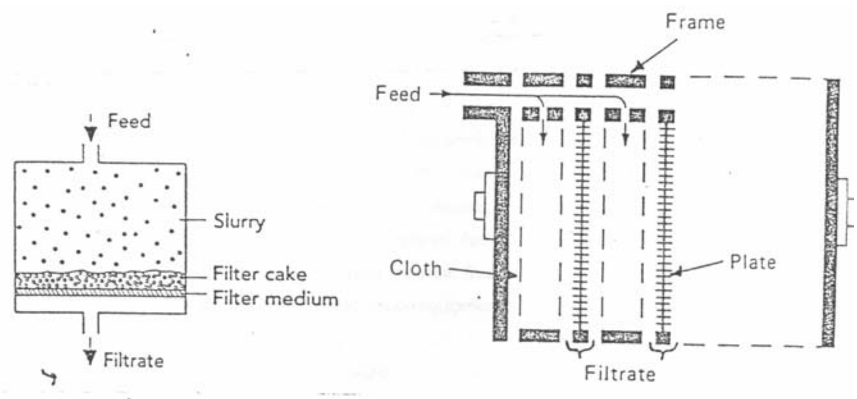
Figure 9.8: Schematic diagram of a hydraulic juice press

9.3.7 Decanter

A high solid stream can be partially clarified using decanters and finishers. Both pieces of equipment operate on the principle of a spinning central cone, drum, or set of paddles pushing the juice through a screen of some type. The unit is typically mounted horizontally, and throughput is relatively high. Total suspended solids may be reduced to 1% or less during operation, depending upon characteristics of the feed stream and operating conditions of the separator.

9.3.8 Filtration Equipment

Finely suspended particles in the juice are removed with a special equipment known as filter press. Filter presses are available with various designs and capacities. The filtering media may be finely woven cloth, canvas, fibre, asbestos pads, cotton or wood pulp discs, porous porcelain wares etc. The frame and filter press is highly effective for clarification of lime juice required for the preparation of lime juice cordial. A schematic diagram, explaining the working principle of frame and filter press is shown in Figure 9.9a and Figure 9.9b.



(a) **(b)**

Figure 9.9: Filters: a) Schematic representation of filtration; b) Plate and frame filter press

9.3.9 Deaerator

Freshly extracted and screened juice contain large amount of oxygen, which should be removed before packing. Most of the air is present on the surface of the juice and some is dissolved in it. The air as well as other gases are removed by subjecting the fresh juice to a high vacuum. This method is highly expensive due to the vacuum creation. The equipment used for the removal of oxygen from the fruit juice is called deaerator. The deaerated juice is heated in a flash pasteurization equipment.

9.3.10 Flash pasteurizer/Rapid Pasteurizer

In this equipment, the juice is heated rapidly to a temperature of about 5.5°C higher than the pasteurization temperature and kept at this temperature for about 10-60 second. By this technique, the loss of flavour and vitamin destruction is minimum and the juice keep a uniformly cloudy appearance. A schematic diagram of flash pasteurization equipment is shown in Figure 9.10.

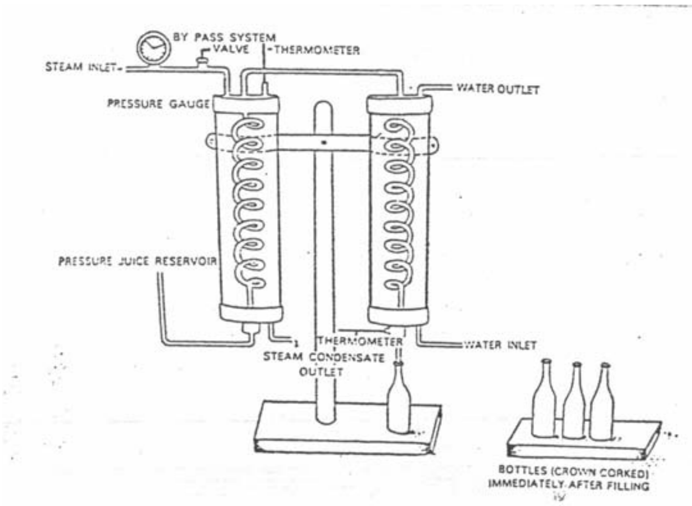


Figure 9.10: Schematic representation of a flash pasteurizer

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain clarification process.

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……………………………………………………………………………………

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2. What is the role of enzymes in juice processing?

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3. What is the difference between pasteurization and flash pasteurization?

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4. What are the methods used for the preservation of juice?

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9.4 SQUASHES

Squash essentially consists of juice containing moderate quantity of fruit pulp to which cane sugar is added for sweetening. According to FPO this type of fruit beverage should contain at least 25% fruit juice or pulp and 40-50 % total soluble solids on weight basis. It also contains about 1.0 % acid and 350-ppm sulphur dioxide or 600 ppm sodium benzoate. It is diluted before serving.

Juice or pulp of fruits is extracted in different ways as discussed earlier. This juice is used for the preparation of squash. Sugar, citric acid, flavouring materials, colour and preservatives are added to the juice in correct proportion. Sugar, citric acid and water are mixed and heated. The dirt is skimmed-off. The clean syrup is blended with the juice. After mixing all the ingredients, a calculated amount of chemical preservative, namely, sodium benzoate or potassium metabisulphite (KMS) is added. Colour and essence can be added to the squash, but should be fairly resistant to the action of preservatives.

The bottles should be cleaned and well sterilized before filling. There should be about 1.2-2.5 cm of head-space in bottles. Bottles are closed with pilfer proof closures, which should be dipped in 1% potassium metabisuphite solution. The bottles are washed, dried and labelled. The product keeps well for more than one year without much change in colour, taste and flavour.

9.5 CORDIAL

This is a sparkling, clear sweetened fruit juice from which pulp and other suspended materials have been completely removed. It contains at least 25% juice and 30% total soluble solids. It also contains about 1.5% acid and 350ppm sulphur dioxide. This is very suitable for blending with wines.

Juice is stored in barrels which are lined with microcrystalline wax. KMS is added as preservative during storage. During storage, the sediment settles and forms a compact layer at the bottom and clear juice remains at the top. Clarification process takes 2-3 months. The clear juice is siphoned off. This method is slow. To make it fast, gelatin and tannin can be added. In clear juice, sugar, water, colour and preservatives are added and the mixture is filtered by means of a filter press. The clear cordial is then bottled.

9.6 SYRUPS

This type of fruit beverage contains at least 25% fruit juice or pulp and 65% total soluble solids. Since the syrup strength is very high, to avoid crystallization, sugar is inverted by adding a small quantity of citric acid and heating in water. It also contains 1.3-1.5% acids and is diluted before serving. Syrups with 65 ^{o}Brix TSS can retain their fresh flavour for over four years. The condition required for this is that a juice should be filtered to a brilliant condition for making the syrup.

9.7 CARBONATED BEVERAGES

The use of fruit juices in the preparation of carbonated drinks is practically unknown in our country. Mostly, artificially flavoured drinks which have no nutritive value are prepared by this method. The use of fruit juices would increase the nutritive value of carbonated beverages.

One of the most important factors that relates to the taste of the bottled fruit juice beverage is carbon dioxide gas content or degree of carbonation. Carbonation is the process of dissolving or incorporating carbon dioxide in a beverage so that when served, it gives off the gas in fine bubbles and has the characteristic pungent taste suitable to the carbonated beverage.

In beverage manufacture, CO_2 not only provides the distinctive taste of carbonated drinks but also inhibits the growth of certain microorganisms. Fruit juices can be carbonated directly or preserved in the form of concentrates for subsequent carbonation. Clarification of such juice is essential prior to carbonation. Carbonated beverage can keep well for about a week without addition of any preservative. For longer storage of carbonated drink, use of preservative (0.05 % sodium benzoate) is necessary.

9.8 FRUIT JUICE CONCENTRATES

Fruit juice concentration offers significant advantages to the processor. Juices obtained by removal of a major part of their water by vacuum evaporation or fractional freezing is termed as “concentrated juices”. By concentrating the juice, the processor reduces the bulk of the juice, thereby reducing storage volume requirement and transportation costs. The process starts with pressing fruits and obtaining pure fruit juice. This is then stabilized by heat treatment which inactivates enzymes and micro-organisms. The next processing step is concentration under vacuum up to 40-65° Brix or 4-7 fold. The concentrates are then blended for standardisation and stored. Many methods are adopted for concentrating fruit juice. They are discussed below:

Evaporation: Evaporation is the most important process for concentration of fruit juices. Production of concentrated juices by evaporation is performed under vacuum (less than 100 mm Hg residual pressure) up to a concentration of 65-70% total sugar which assures preservation without further pasteurization. Modern evaporation installations recover flavours from juices which are then reincorporated in concentrated juices.

Evaporator generally consists of a heat transfer surface, a feed distribution device, a liquid vapour separator and a condenser. A schematic diagram of an evaporator is shown in Figure 9.11. With most of the juices, it is desirable to heat the juice for as short time as possible and rapidly cool the product. This minimizes the effect on flavour, aroma, and sugar components.

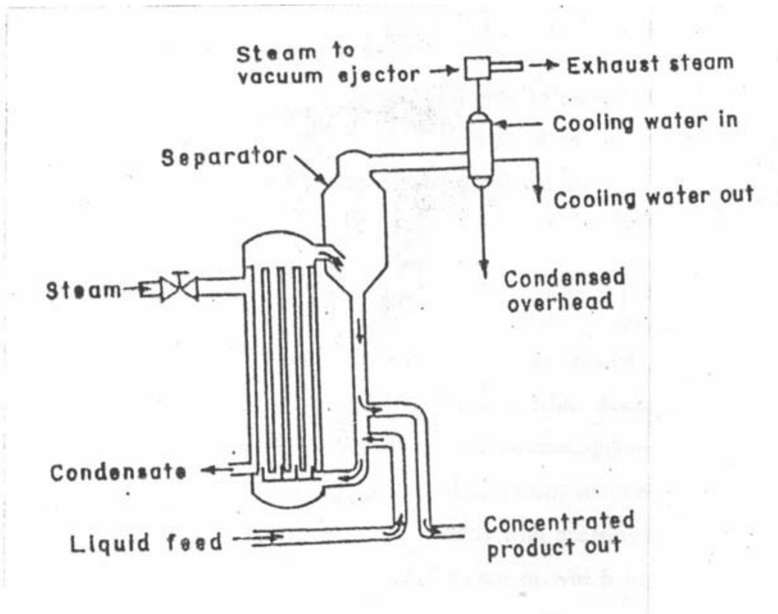

Figure 9.11: Diagram of a typical evaporator

Membrane concentration: Membranes are available that can effectively separate water molecules from other food constituents. Concentration of juice is also possible by using combination of reverse osmosis and evaporation. Specific membranes are used for this purpose. The principle involved is the interposition of a membrane between the feed stream and a transfer stream, and the establishment of conditions providing a driving force for the transport of water across the membrane from the feed to the transfer stream. A schematic diagram explaining the working principle of membrane concentration is shown in Figure 9.12.

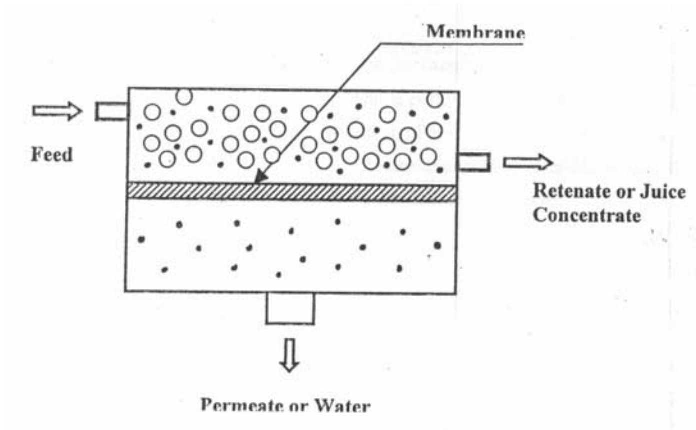

Figure 9.12: Schematic representation of ultrafiltration process

The reverse osmosis technology is effective in concentrating a low solid juice (7-8 ^{o}Brix) two or three fold. From there, use of evaporation technology would be appropriate. Recently, a new reverse osmosis design has claimed effectiveness in achieving a 50-60 ^{o}Brix concentrate. These fruit juice concentrates are often further stabilised by the addition of sodium benzoate and potassium sorbate and are usually stored away from light and are refrigerated or frozen.

Membrane concentration has many advantages over the other concentration techniques. Since the temperature of the processing is less, product quality is maintained. Lower energy requirements, lower labour costs, lower floor space, and wide flexibility are other advantages.

Freeze concentration: This process is based on freezing point depression. Pure water freezes at a temperature of 0^oC. However, if dry solid is dissolved, freezing take place at further low temperatures. In this process a freezer is used to produce ice crystals out of fresh juice and a device is used for separating these ice crystals. The separation of ice crystals from the juice slurry is done by using a centrifuge or filter press.

Freeze concentration avoids the problems associated with evaporation methods that depend upon the heat. It is capable of concentrating most juices to 50^oBrix without appreciable loss of taste, aroma, colour or nutritive value.

9.9 FRUIT JUICE POWDERS

In this method juices are preserved in the form of powder. The juice is sprayed as mist into an evaporating chamber and the flow of air is so regulated that dried juice falls to the floor of the chamber in the form of dry powder. The powder is then separated and packed air tightly. The powder, when dissolved in water makes a fruit drink almost similar to its original fresh juice.

Many fruit juices can be dehydrated to powders or crystals for reconstituting into beverages and are available at prices comparable with quality frozen concentrates. These powdered products are available in several sizes of package. Additives which are permitted by FDA are usually included. These powdered products are also considered as "sports drink", which requires mixing by the individuals and avoids the inconvenience of transporting large volume of liquid.

These powders are highly hygroscopic in nature and hence require proper packaging. Fruit juice powder from fruits like oranges, mangoes, jackfruit, guava etc. are prepared from strained fruit juices either by spray drying or puff drying and pulp can be used as the base material for baby foods. The powders can be made by vacuum drying, spray drying, freeze drying, drum drying or by foam-mat drying. The moisture content of powdered juice varies from 3-5%. The methods and principles of these drying processes are explained in unit 4 (Section 4.9).

9.10 QUALITY

The term 'quality' is one of the most defined terms in use in the food industry today. Quality may be defined as 'The totality of features and characteristics of a product that bear on its ability to satisfy a given need'. The first part, 'The totality of features and characteristics of a product…..'concerns objective factors related to the product. The second part, '……to satisfy a given need', concerns subjective factors related to the user or the consumer of the goods.

9.10.1 Factors Influencing Product Quality

To produce high-quality products, the processor needs to be aware of the quality attributes which the consumer discerns as most important and which are most relevant in determining acceptability. Most consumers would initially judge the acceptability of products on their appearance, flavour, texture and perceived nutritional benefits. Each of these attributes is a function of the bio-chemical and physico-chemical composition of the fruit or vegetable. This is influenced by various factors viz:

1. The quality and composition of the raw materials,
2. The effects of processing,
3. The effects of environmental factors, such as temperature, oxygen, light and moisture, encountered during storage and distribution,
4. Customer handling and use, and
5. The barriers to these factors provided by the packaging.

9.10.2 Measurement of Product Quality

One obvious way of measuring product quality is to monitor sales and customer complaints; the higher the sales and the fewer the complaints, the more likely one is to be satisfying the consumer requirements. However, no responsible food manufacturer would rely on this as their only method of quality control. Various methods used for the evaluation are:

1. Instrumental,
2. Immunoassay,
3. Near infrared spectroscopy, and
4. Sensory evaluation.

9.10.3 Quality Control Measures

Some of the important points to be considered for maintaining good quality products are as follows:

1. Only sound fruits or vegetables of sufficient maturity are to be used for processing.
2. Adequate hygienic practices should be followed during the processing of the product.
3. The inspector must be aware of the pesticides and other chemicals used in the production of the raw materials. Necessary laboratory analyses can then be arranged to ensure residue levels in the final product.
4. At the commencement of and during processing, the inspector should pay attention to the state of raw materials, the preparation of raw materials for processing (peeling, slicing, dicing, blanching, etc.), preparation and density of packing medium (sugar syrup, salt brine, etc.), the state of containers to be used (cleanliness and strength), the pasteurization or freezing process (time/temperature relationship), bottle filling and capping and bottle/container storage.
5. The people who work in the processing plant must maintain a high degree of personal cleanliness and conform to hygienic practices while on duty.
6. Persons who are monitoring the sanitation programs must have the education and/or experience to demonstrate that they are qualified.

7. Plant construction and design shall provide enough space for sanitary arrangement of equipments. The equipments must be self-cleanable as far as possible. Cleaning operations must be conducted in a manner that will minimize the possibility of contaminating foods or equipment surfaces that contact food.
8. Check the final product to ensure the vacuum and headspace, packing medium strength and container conditions. Statistically based sampling plans should be adopted for the examination of final product to ensure that it meets the requirements of the export regulations.
9. Each processing unit should have its own sufficiently equipped laboratory and staff to carry out physical, chemical and microbiological quality examinations of the goods.
10. Practice proper sanitary handling procedures. Cleaning operations must be conducted in a manner that will minimize the possibility of contaminating foods or equipment surfaces that contact food

9.10.4 Labelling

Customers and consumers expect the labelling on food to be a true description of what they are buying. Misleading or fraudulent labelling is an unfair trade practice that cannot be tolerated. The important requirements of a label are as follows:

1. A statement of identity,
2. A declaration of net contents (weight or volume),
3. The name and address of the manufacturer, packer, and
4. A list of ingredients (in descending order of volume or weight).

In addition, labels may also be required to include, amongst other things, the country of origin, date of manufacture or packing, a use-by or expiry date, nutritional qualities or values of the food, storage directions, a quality grade and directions for consumption.

9.11 STANDARDS

Government of India has made statutory provision for the control of quality. This has been made to maintain the quality of food, to prevent exploitation of the consumer by the sellers, to safeguard the health of consumers and to establish a criteria for the quality of food products. By this provision we can easily identify the quality of the processed products.

Fruit Products Order (FPO) – 1955, promulgated under Section 3 of the Essential Commodities Act – 1955, aims at regulating sanitary and hygienic conditions during the manufacture of fruit products. It is mandatory for all manufacturers of fruit and vegetable products to obtain a license under this Order. This act regulates the manufacture, storage and sale of fruit and vegetable products.

The FPO 1955 was issued by the Department of Food, Ministry of Food Processing Industries under the powers vested in the government under the Essential Commodities Act to ensure the quality of fruit and vegetable products. This order controls the production, distribution and quality of the fruits and vegetable products manufactured in the country as well as registration, licensing and operation of manufacturing units.

The FPO mark is given to the processor after the grant of license for manufacturing fruit or vegetable product, after the inspection of factory for hygiene and sanitation. FPO mark and license number is required by law to be exhibited on labels of each processed item along with the other information as laid down in the FPO rules.

The FPO specifications includes methods of preservation, permissible colours in the preparations and also the minimum quality requirements of the final products. Fruit and vegetable products which do not conform to the FPO specifications are considered adulterated.

FPO specifications for fruit beverages are as follows:

Sl. No.	Particulars	Specifications	
		Minimum % of TSS in final product	Minimum % of fruit juice or prepared fruit in final product
1.	Fruit Syrup	65	25
2.	Squash	40	25
3.	Cordial	30	25
4.	Unsweetened Juice	Natural	100
5.	Sweetened Juice	10	85
6.	Fruit Juice concentrate	32	100

Permissible limits of preservatives in fruit beverages:

Sl. No.	Fruit beverage	Preservative	Maximum level permitted (mlp)
1.	Fruit juice concentrate	Sulfur dioxide	1500
2.	Squashes, fruit syrups, cordials, fruit juices	Sulfur dioxide or Benzoic acid	350 600

9.12 PACKAGING

Packaging is an integral part of food processing. It performs two main functions: to protect the processed product from surroundings and to advertise the product at the point of sale. The main factors that cause deterioration of product during storage are as follows.

1. Mechanical forces (Impact, vibration, compression etc.),
2. Climatic influences that cause physical or chemical changes (UV light, moisture, oxygen, temperature changes),
3. Contamination (by microorganism, insects, or soil), and
4. Pilferage, tampering or adulteration.

9.12.1 Requirements and Functions of Packaging Materials

The following are among the more important general requirements and functions of food packaging materials/ containers:

1. They must be non-toxic and compatible with the specific foods.
2. Sanitary protection and light protection.
3. Moisture, gas, odour and fat protection.
4. Resistance to impact or other external forces.
5. Transparency.
6. Ease of opening and ease of disposal.
7. Pouring features and reseal features.
8. Size, shape, weight limitations.
9. Appearance and printability.
10. Low cost and other special features.
11. Eco-friendly.

9.12.2 Types of Packaging Materials

There are two main groups of containers: i) Shipping containers, and ii) Retail containers. Shipping containers are containers which contain and protect the contents during transport and distribution (e.g. Wooden, metal or fibreboard cases, crates, barrels, drums and sacks). Where as the retail containers are consumer units which protect and advertise the food in convenient quantities for retail sale and home storage.(e.g.: metal cans, glass bottles, jars, rigid and semi-rigid plastic tubs, collapsible tubes, paperboard cartons and flexible plastic bags).

Wooden containers: Wood offers good mechanical protection and good stacking characteristics. The bottles of fruit beverages are transported by the use of wooden crates. Boxes, crates, casks, kegs, pallets, and few other types of containers made of wood are used on a limited scale to package food products.

Textiles: Cotton bags, sacks and bales are also used in the shipping of food products. They have limited use in the packaging of larger quantities of some products. Open mesh bags are frequently used to pack products such as fresh vegetables, which require complete ventilation in transport and storage.

Metal Can: Metal cans have a number of advantages over other types of containers. These includes protection, convenience for ambient storage and tamper proof. However the cost and weight of metal containers are relatively high. The usual metal cans used are three piece cans, two-piece cans, aerosol cans and aluminum cans.

Tinplate is the common material used for metal cans. It is a rigid and impervious material, consisting of a thin sheet of low carbon steel coated with a very thin layer of tin. Tin is not completely resistant to corrosion but its rate of reaction with many food materials is considerably slower than that of steel. Some organic coatings are provided to protect the tin surface. The FDA approved coating used for the fruit beverage is known as "Beverage can enamel" The coatings not only protect the metal from corrosion by food constituents but also protect the foods from metal contamination.

Glass: There is more use of glass in food industry. Glass containers are chemically inert and do not react with or migrate into food products. They are resealable, recyclable, reusable and are transparent to microwaves. They are transparent to display the contents and impervious to moisture, gases, odours and microorganisms. The principal limitation of glass is its susceptibility to breakage, which may be from internal pressure, impact, or thermal shock, all of which can be greatly minimised by proper matching of the container to its intended use and intelligent handling practices. Main classes of glass receptacles are:

1. Jars which are resistant to heat treatments,
2. Jars, glasses, etc. for products not submitted to heat treatment (marmalades, acidified vegetables, etc.),
3. Glass bottles for pasteurized products (tomato juice, fruit juices, etc.) or not pasteurized (syrups), and
4. Receptacles with higher capacity.

Flexible Films: Flexible packaging describes any type of material that is not rigid. In general they are heat sealable, suitable for high speed filling, suitable for printing and add little weight to the product. They fit closely to the shape of the food, thereby wastage of space is less during transportation and storage. In most cases, such films are used in the construction of inner containers. Since they are non-rigid, their main functions are to contain the product and protect it from contact with air or water vapour. Their capacity to protect against mechanical damage is limited, particularly when thin films are considered.

Flexible films includes single films (e.g.: poly ethylene, poly ester, etc.), coated films (e.g.: films coated with aluminium), laminated films (lamination of two or more films) and co-extruded films.

Paper and paper board: Paper and paper board are used in a variety of package types and forms. Paper from wood pulp and reprocessed waste paper will be bleached and coated or impregnated with such materials as waxes, resins, lacquers, plastics, and laminations of aluminium. This is to improve water vapour and gas impermeability, flexibility, tear resistance, burst strength, wet strength, grease resistance, sealability, appearance, printability, etc.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between fruit juice and squash.

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2. How is syrup different from cordial?

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3. What are the different methods to produce juice concentrate?

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4. How is juice powder made?

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9.13 LET US SUM UP

The fruit beverage industry is gaining popularity because of nutritional superiority of these beverages to synthetic and aerated drinks. We have discussed in detail about the preparation of a variety of fruit beverages viz., juices, squash, syrup, fruit juice concentrate and fruit juice powder.

The various methodologies adopted in preservation and the working principles of different equipments used in processing of fruit beverages are briefly described in this unit. In addition, the packaging requirements, types of packaging materials, quality aspects and standards of fruit beverages are explained in detail.

9.14 KEY WORDS

Disintegration : Size reduction of fruit

Enzyme : Enzymes are organic biocatalysts which govern, initiates and control biological reactions important for life processes.

Expression : Separation of liquids from solids by applying pressure.

Filtration : Separation of solids from liquids by passing the mixture through a bed of porous material.

Brix : Unit for the measurement of Total Soluble Solids present in fruit beverage.

TSS	:	Total Soluble Solids is the amount of sugars and water soluble substances present in fruit and vegetables.
Clarification	:	It is the process of complete removal of all suspended material from the juice
Centrifugation	:	The separation of immiscible liquids, or solids from liquids by the application of centrifugal force.
De-tartarisation	:	Elimination of potassium bi-tartrate from fruit beverage.
Pasteurization	:	It is the process of heat treatment used to reduce the total microflora, especially pathogenic bacteria.
Flash pasteurization	:	It is the process of heating fruit juice for a short time at a temperature higher than the pasteurization temperature and held at that temperature for about one minute.
Carbonation	:	It is the process of dissolving sufficient carbon dioxide in fruit juice
Decanter	:	It is the process of removal of suspended material from the juice.
Deaerator	:	The equipment used for the removal of oxygen from the fruit juice.
Squash	:	Fruit beverage which contain at least 25% fruit juice or pulp and 40-50 % TSS.
Cordial	:	Fruit beverage which contain at least 25% juice and 30% TSS.
Syrups	:	Fruit beverage which contains at least 25% fruit juice or pulp and 65% TSS.
Evaporation	:	It is the partial removal of water from liquid foods by boiling.

9.15 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Clarification is the process of complete removal of all suspended material from the juice**.** This can be performed by many methods viz. centrifugation, enzyme treatment, settling, filtration, freezing(-18°C), use of high temperature (nearly 82°C) and low temperature(-2 to –3 °C). The chemical treatments like addition of gelatin, albumin, casein, or a mixture of tannin and gelatin is also used for the removal of suspended particles.

2. The enzyme treatments during crushing process will enhance the extraction yield, the juice colour is better fixed and finished product taste is improved.

3. Pasteurization is the process of heating fruit juice at boiling temperature or slightly below it for a sufficient length of time to kill the microorganisms which cause spoilage. Whereas flash pasteurization is the process of heating fruit juice for a short time at a temperature higher than the pasteurization temperature and held at that temperature for about one minute.

4. Preservation of fruit juice can be done by addition of sugar, pasteurization, flash pasteurization, freezing, drying, carbonation, filtration, irradiation and by adding chemicals like sulfur dioxide or Benzoic acid.

Check Your Progress Exercise 2

1. Fresh fruit juice contain 100 % fruit juice, where as fruit beverage which contain at least 25% fruit juice or pulp and 40-50 % TSS is known as squash.

2. Cordial is a fruit beverage which contain at least 25% juice and 30% TSS, where as syrups contains at least 25% fruit juice or pulp and 65% TSS.

3. Various methods used for fruit juice concentration are: Evaporation, Freeze concentration and Membrane concentration.

4. Fruit juice powders are prepared from strained fruit juices by spray drying, vacuum drying, freeze drying, drum drying or by foam-mat drying. However spray drying is the most common method. The juice is sprayed as mist into an evaporating chamber and the flow of air is so regulated that dried juice falls to the floor of the chamber in the form of dry powder.

9.15 SOME USEFUL BOOKS

1. Mahadeviah, M. and Gowramma, R.V. (1990). Food Packaging Materials, Tata McGraw Hill Publishing Company Ltd. New Delhi.

2. Somogyi, L.P, Barrett, D.M. and Hui, Y.H. (1996). Processing of Fruits: Science & Technology (Vol. II) – Major Processed Products, Technomic Publishing Co. Inc., Lancaster, USA.

3. Srivastava, R.P. and Kumar, Sanjeev (1998). Fruits and Vegetable Preservation – Principles and Practices, International Book Distributing Co., Lucknow.

UNIT 10 JAMS, JELLIES, MARMALADE AND OTHER SUGAR-BASED PRODUCTS

Structure

10.0 OBJECTIVES

By the time you have studied this unit, you should be able to describe:

- importance of sugar, sweeteners, confections and sugar substitutes;
- types and sources of sugar and its role in food systems;

- methods of preparation of fruit jam, jelly, marmalade and other sugar-based products; and
- special care to be taken during the preparation of these sugar based products.

10.1 INTRODUCTION

Though India ranks first in the total production of fruits and vegetables, an appreciable amount of the produce is culled or of inferior quality. These culled fruits can be effectively utilised for the preparation of value added products like jam, jelly, marmalade, preserves, candies and other sugar based products.

The preparation of such sugar based products is one of the most important aspects of home scale preservation as well as industrial level processing of fruits. This method of preservation with high sugar concentration is principally based on the reduction in moisture content so as to arrest the microbial spoilage.

In this unit, first we'll learn about the various types of sugars, sweeteners, and their sources. The role of sugar in food system is dealt with. The preparation of the sugar based products and the special care taken during processing is described in detail. The quality aspects and packaging are also briefed in this section.

10.2 SUGAR

Sugars are carbohydrates, an important source of energy for the body. When we talk about sugar we usually refer to table sugar or sucrose, from cane or beet. There are many other types of sugars. Some occur naturally in fruits, vegetables and milk.

All sugars provide the same amount of calories (approximately 4 kilo calories or 16 kilo Joules per gram) and impart sweetness. There are two general classes of sweeteners – nutritive and non-nutritive. Nutritive sweeteners contain calories and provide energy, while non-nutritive sweeteners have no calories and provide no energy. Sucrose is the major nutritive sweetener; other sweeteners of this group are starch hydrolysates HFCS, glucose, fructose, lactose, polyols, maple syrup and honey. Examples of non-nutritive sweeteners are saccharin, acesulfame K, aspartame, etc.

10.2.1 Sources of Sugar

Sucrose is available in a variety of plant sources. However, the two most important sources of sugar for commercial production include sugarcane and sugar beet. In India, sugar is manufactured from sugarcane in the form of jaggery, open pan sugar, and vacuum pan sugar.

Sugar from Sugarcane

Jaggery: It is obtained mostly from sugarcane and also from palmyra, date palm and coconut. The harvested sugarcane is crushed to obtain juice. The sugarcane juice so obtained is freed from coarse suspended impurities and boiled in open pans. Jaggery has a light colour, good flavour, hardness and crystalline structure with good keeping quality. It contains about 65-85% sucrose, 10-15% invert sugar and 2.5% ash. Jaggery finds use in the preparation of non -crystalline candies and a variety of sweets.

Khandasari sugar: This is obtained by boiling the clarified sugarcane juice quickly to a required consistency to introduce the crystallization of sugar. The crystals are recovered by centrifugation and dried.

Sugar: It is manufactured from sugarcane juice in three different form, raw sugar, refined sugar and white sugar. The juice obtained by pressing the sugarcane is dark green in colour and turbid. It is mildly acidic with a pH of 5-5.4 and the sucrose content is 10-18%. This juice on filtration, evaporation and centrifugation will give raw sugar, which contain 96-97% sucrose. This raw sugar on refining will give refined and white sugar. The recovery of sugar is about 10-11%weight of sugarcane.

Sugar from Sugar Beet

Beet sugar is obtained from sugar beet. The clear liquid extracted from sugar beet on evaporation with controlled temperature yields a thick syrup. Raw sugar crystals are obtained from this thick syrup. The raw sugar on purification gives white sugar. Powdered sugar for icing of confectionary, cake and bakery products is made by pulverizing granulated sugar with or without edible starch.

10.2.2 Sweeteners

They are manufactured mainly from any starch source such as wheat, maize or corn, and are liquefied in the presence of enzymes. The liquid then undergoes saccharification after it is cooled to about 60^{o}C or so. Various types of sweeteners of this group are discussed below.

Starch hydrolysates: Starch syrup (glucose or maltose syrup), dried starch syrup, glucose and high fructose syrup are some of the sweeteners derived from starch degradation. Starch saccharification is carried out by either acidic or enzymatic hydrolysis under controlled processing conditions to yield starch hydrolysates with different composition to suit the diversified requirements. Their industrial uses include manufacture of soft caramel candies, alcoholic beverages and soft drinks, canning and processing of fruits and vegetables.

High fructose corn syrup: The commercial value of high fructose corn syrup (HFCS) is based on their increased sweetness as compared to the starting material, glucose, obtained from starch. The manufacturing process of HFCS include the use of specific enzymes for the liquefaction of starch, saccharification and isomerisation. The refined dextrose liquor is concentrated or blended to a dry solid level of 40-50%.

Glucose (Dextrose): Starch from corn, potatoes or wheat is saccharified enzymatically by α-amylase and /or microbial amyloglucosidase. After starch hydrolysis the product will contain 95% glucose. The syrup is purified and evaporated to crystallize glucose as α-D-glucose mono hydrate. Drying or crystallization gives the anhydrous form. Glucose is used as invigorating and strengthening agent in many nourishing formulations.

Fructose: Fructose is obtained by acid hydrolysis of inulin, a natural polymer of fructose found in tubers. Fructose is 1.5 times sweeter than sucrose and is used as sugar substitute for diabetics.

Lactose: Lactose is prepared from whey concentrates. The concentrate is heated, filtered, and evaporates to yield a yellow lactose. This raw lactose on filtration and crystallization will give α-D lactose monohydrate. β-lactose which is more soluble and easily digestible compared to α-lactose is also obtained by heating lactose solution.

Sugar alcohols: Polyols are so-called sugar alcohols. They do occur naturally but most are made commercially by the transformation of sugars. Isomalt is the most commonly used polyol and is derived from sucrose. Polyols are sweet and can be used in foods in a similar way to sugars although they can have a laxative effect when eaten in large quantities. Sugar alcohols are slightly lower in calories than sugar and do not cause a sudden increase in blood glucose. They include sorbitol, xylitol, lactitol, mannitol, and maltitol and are used mainly to sweeten sugar-free candies, cookies, and chewing gums.

Maple syrup: Maple syrup with sugar content of about 65% is obtained by evaporating the sap of maple tree. The sap from the tree has no flavour but develops a special flavour during evaporation. Maple syrup is used as a sweetener and as a flavouring agent.

Honey: Honey is produced by honeybees which suck up the nectar and honey due from flowers and other sweet saps of plants and store the nectar in their honey sac or pouch. Based on its end use, honey is classified as honey for domestic use of highest purity and bakery honey of less purity. Honey is marketed as liquid or as semisolid creamed honey and contains about 38% fructose, 31% glucose and 2% sucrose.

10.2.3 Confections

Chocolate confectionery: Chocolate is made from non-alkalized cocoa liquor by mixing with sucrose, cocoa butter and aroma substances including milk solids, nuts, coffee paste etc.. The ingredients are processed through several steps to yield a final product. The various processing steps include mixing, refining, ripening, conching, tempering and molding. The finished chocolate contains at least 40% cocoa liquor or a blend of liquor and cocoa butter and up to 60% sugar. Cocoa and chocolate products require careful storage condition of dry (55-65% humidity), cool (10-12^{o}C), well aerated space protected from light and odourous substances.

Sugar confectionery: Sugar confectionery includes both crystalline and amorphous types made from boiled sugar syrup. The temperature of boiling sugar solution and ingredients used will determine the nature of the end product. Crystalline confectionery or candies have a smooth texture, amenable for cutting with knife and easily chewable. Amorphous candies have a heterogeneous soft structure and break into pieces rather than be cut with knife.

Crystalline confectionery is made by adding ingredients such as invert sugar, glucose or corn syrup, which aid the formation of fine sugar crystals from sugar syrup. Amorphous confectionery is made by preventing crystallization of the sugar either by cooking the sugar solution at high temperature and allowing the product to harden quickly or by adding large amounts of ingredients, which inhibit crystallization.

10.2.4 Role of Sugar in Food Systems

Sugar (glucose) is the primary energy source. Sugar is used to improve the palatability of many foods and can thereby encourage a more varied diet. Using sugars can improve the texture and colour of baked goods. Sugars produce the moistness, attractive colour and crispy texture to food products. The various functional properties of sugar in food system include:

- Source of energy
- Nutritional aspects
- Flavour and colour production
- Sweetening
- Texturing
- Plasticizing action and
- Humectancy

10.2.5 Types of Sugar

Because of its diverse functional characteristics, sugar is used in many types of food preparation. Although this handbook focuses on the functions of "regular" sugar, the most common type used in the home, sugar is available in many other forms.

Granulated Sugar

There are many types of granulated sugar. Most of them are used only by food processors and professional bakers and are not available in the market. The types of granulated sugars differ in crystal size. Each crystal size provides unique functional characteristics that make the sugar appropriate for the food processors' special need.

Regular sugar, extra fine or fine sugar: "Regular" sugar, as you know, is the sugar found in every home's sugar bowl and most commonly used in home food preparation. It is the white sugar called for in most cookbook recipes. The food processing industry describes "regular" sugar as extra fine or fine sugar. It is the sugar most used by food processors because of its fine crystals that are ideal for bulk handling and are not susceptible to caking.

Fruit sugar: Fruit sugar is slightly finer than "regular" sugar and is used in dry mixes such as gelatin desserts, pudding mixes and drink mixes. Fruit sugar has a more uniform crystal size than "regular" sugar. The uniformity of crystal size prevents separation or settling of smaller crystals to the bottom of the box, an important quality in dry mixes and drink mixes.

Bakers special: Bakers Special's crystal size is even finer than that of fruit sugar. As its name suggests, it was developed specially for the baking industry. Bakers Special is used for sugaring doughnuts and cookies as well as in some commercial cakes to produce fine crumb texture.

Superfine, ultra-fine, or bar sugar: This sugar's crystal size is the finest of all the types of granulated sugar. It is ideal for extra fine textured cakes and meringues, as well as for sweetening fruits and iced-drinks since it dissolves easily.

Confectioners/powdered sugar: This sugar is granulated sugar ground to a smooth powder and then sifted. It contains about 3% cornstarch to prevent caking. Confectioners sugar is available in three grades ground to different degrees of fineness. The confectioners sugar available in supermarkets is the finest of the three and is used in icings, confections and whipping cream. Industrial bakers use the other two types of powdered sugar.

Coarse sugar: The crystal size of coarse sugar is larger than that of "regular" sugar. Coarse sugar is normally processed from the purest sugar liquor. This processing method makes coarse sugar highly resistant to colour change or inversion (natural breakdown to fructose and glucose) at high temperatures. These characteristics are important in making fondants, confections and liquors.

Sanding sugar: Another large crystal sugar, sanding sugar, is used mainly in the baking and confectionery industries to sprinkle on top of baked goods. The large crystals reflect light and give the product a sparkling appearance.

Jaggery

Brown sugars come in many different styles but are essentially one of the two types: sticky browns and free-flowing browns. The sticky browns were originally the sort of mixture that comes out of a cane sugar crystallizing pan. The extreme of this, still made in India today, is "jaggery" or "gur" which is essentially such a mixture boiled until dry. Brown sugar consists of sugar crystals coated in a molasses syrup with natural flavour and colour. Dark brown sugar has more colour and a stronger molasses flavour than light brown sugar. Lighter types are generally used in baking and making butterscotch, condiments and glazes. Dark brown sugar has a rich flavour that is good for gingerbread, mincemeat, baked beans, plum pudding and other full flavoured foods.

Free flowing brown sugars: These sugars are fine, powder-like brown sugars that are less moist than "regular" brown sugar. Since it is less moist it does not lump and is free-flowing like granulated white sugar.

Burnt sugar / caramelized sugar: Sugar caramelized by cooking at high temperature. Prepared in specialty items requiring a special flavour and colour. Not available for purchase, but can be made at home.

Liquid Sugars

Liquid sugar syrup: There are several types of liquid sugar. Liquid sucrose (sugar) is essentially liquid granulated sugar and can be used in products wherever dissolved granulated sugar might be used. Amber liquid sucrose is darker in colour and can be used where the cane sugar flavour is desirable and the non-sugars' are not a problem in the product. Granulated white sugar dissolves in water. They are used in beverages, jams, candy, ice cream, syrups, and cooked fondants.

Invert sugar: Inversion or chemical breakdown of sucrose results in invert sugar, an equal mixture of glucose and fructose. Available commercially only in liquid form, invert sugar is sweeter than granulated sugar. One form of liquid invert was specially developed for the carbonated beverage industry and can be used only in liquid products. It is used mainly in food products to retard crystallization of sugar and retain moisture. This can also be used in confectionery, canning and baking

10.2.6 Sugar Substitutes

Artificial sweeteners are non-nutritive (zero calories per serving), high intensity sugar substitutes. These are sweet synthetic substances, often used in place of other sugars in food manufacturing and cooking. One packet of these sweeteners is equivalent to the sweetness of 2 tones of table sugar. No low calorie sweetener is perfect for all uses. They provide products with increased stability, improved taste, lower production costs and more choices for the consumer. They have very long shelf lives and can be stored in original packaging in a dry location at room temperature. Some of the non-nutritive sweeteners used in food are saccharin, acesulfame K, aspartame, sucralose, Alitame, Cyclamate and stevia.

Saccharin is 300 times sweeter than sugar, but has a slightly bitter or metallic aftertaste. Saccharin is available under the trade name "*Sweet'N Low*". It is currently produced from a purified compound found in coal tar. It is not metabolized in the digestive tract and is excreted rapidly in the urine. As a result, saccharin does not contribute calories to the diet. Saccharin continues to be important for a wide range of low-calorie and sugar-free beverage applications. Saccharin also is used in cosmetic products, vitamins and pharmaceuticals.

Acesulfame K: Acesulfame K Acesulfame potassium) is 200 times sweeter than table sugar. Its trade name is *Sunette*. The chemical structure is similar to saccharin. This is used in baked goods, frozen desserts, beverages, and candies. It has excellent shelf life and does not break down when cooked or baked. It does not provide calories since the body does not metabolize it and it is excreted in the urine without being changed. Acesulfame-K is usually used in combination with aspartame or other sweeteners because it enhances and sustains the sweet taste of foods and beverages and helps to extend the shelf life of the food product.

Aspartame: It is produced from two amino acids aspartic acid and *phenylalanine* and is 180 times sweeter than sucrose. The trade name of Aspartame is *"NutraSweet"* and *"Equal*". During digestion, aspartame is broken down into these two individual amino acids. It is also broken down when exposed to heat, resulting in a loss of its sweet taste.

Sucralose: It is known by its trade name, "*Splenda*". It is 600 times sweeter than sugar and is used in baked goods, beverages, gelatin, and frozen dairy desserts. Sucralose is derived from sucrose (table sugar). It closely resembles table sugar in taste, is highly water-soluble, and is exceptionally stable at high temperatures. Sucralose is not absorbed from the digestive tract, so it adds no calories to consumed food. In addition, sucralose does not increase blood sugar levels. Because sucralose is so much sweeter than sugar, it is bulked up with malto-dextrin, a starchy powder, so it will measure more like sugar. It has good shelf life and doesn't degrade when exposed to heat.

Alitame: Like aspartame, alitame is made from amino acids, D-alanine and L-aspartic acid. Alitame is 2,000 times sweeter than sugar. It is currently approved for use in Australia, New Zealand, Mexico, and China.

Cyclamate: It was initially marketed as tablets that were recommended for use as a tabletop sweetener for people with diabetes and others who had to restrict their intake of sugar. Although it is approved for use in many countries, cyclamate is banned in the United States due to concerns over potential carcinogenicity.

Stevia: This is derived from a shrub. The cultivation of this plant in our country has increased in recent years. Though it can impart a sweet taste to foods, it cannot be sold as a sweetener because it is an unapproved food additive. However, stevia can be sold as a "dietary supplement", though it cannot be promoted as a sweetener.

10.2.7 Role of Sugar in Jams, Jellies and Other Sugar-based Fruit Products

Recipes use just about one part fruit to one part sugar in jams, jellies, and preserves. In these foods, sugar helps to retain the original flavour, aroma, colour and other quality attributes of the fruit. Fruit flavours are condensed and strengthened, resulting in the distinctive texture and pleasant appearance of jellies and preserves.

During gel formation, pectin, a natural component of fruits, forms a gel only in the presence of sugar and acid. Sugar prevents spoilage of jams, jellies, and preserves after the container is opened. Once the jam jar is opened, sugar attracts all water and water is transferred from the microorganisms into the concentrated sugar syrup. The micro flora is dehydrated and laid up, and cannot multiply further.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the role of sugar in food products?

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2. What do you mean by sugar alcohol? Give any two examples.

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3. What are artificial sweeteners? Give any two examples.

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10.3 FRUIT JAM

Jam is a product with reasonably thick consistency, firm enough to hold the fruit tissues in position and is made by boiling fruit pulp with sufficient sugar. Jams contain 0.5-0.6% acid and invert sugar should not be more than 40%. FPO specifications for jam are given in section no. 2.14.

10.3.1 Preparation of Jam

Jam can be prepared from one kind of fruit or from two or more kinds. It may be made from practically all varieties of fruit. Apple, papaya, carrot, strawberry, mango, grapes, pineapple, etc. are used for the preparation of jams. Various combinations of different varieties of fruit can be often made to advantage, pineapple being one of the best for blending purposes because of its pronounced flavour and acidity.

Preparation of fruit pulp: Sound fruit is sorted, washed in running water or, preferably, brush-washed and prepared. The mode of preparation varies with the nature of the fruit. For example, mangoes are peeled, steamed and pulped; apples are peeled, cored, sliced, heated with water and pulped; plums are scalded and pulped; peaches are peeled and pulped; apricots are halved, steamed and pulped; berries are heated with water and pulped or cooked as such.

Addition of sugar: To make jams and jellies, up to a maximum of 25% of corn syrup for sweetness can be utilized. Generally, cane sugar of good quality is used in the preparation of jams. The proportion of sugar to fruit varies with type and variety of fruit, its stage of ripeness and acidity. A fruit pulp to sugar ratio of 1:1 is generally followed. This ratio is usually suited to fruits viz., berries, currants, plums, apricots, pineapple and other tart fruits.

Addition of acid: Citric, malic or tartaric acids are present naturally in different fruits. These acids are also added to supplement the acidity of the fruits deficient in natural acids during jam making. Addition of acid becomes necessary as adequate proportion of sugar- pectin- acid is required to give good set to the jam. The recommended pH for the mixture of fruit juice and pectin is 3.1. The acidity of finished jam varies between 0.5 to 0.7 % depending on the type of the jam. It is often advisable to add acid at the end of cooking which leads to more inversion of sugar. When acid is added in the beginning, it will result in poor set.

Processing/boiling: Fruit pulp is cooked with the requisite quantities of sugar and pectin, and finished to 69% Total Soluble Solids (TSS). Permitted food colours, requisite amount of citric acid and flavourings are added at this stage. The boiling process, in addition to excess water removal, also partially inverts the sugar, develops the flavour and texture. During jam boiling, all micro-organisms are destroyed within the product. When this is filled hot into clean receptacles which are subsequently sealed, and then inverted the hot jam contacts the lid surface, thus prevents the spoilage by micro-organisms during storage.

10.3.2 Judging of End Point

Concentration of jam is finished at an optimum point avoiding over cooking which leads to economic losses due to less yield. But under cooking will result in the spoilage of jam during storage due to fermentation. The finishing or end point of jam can be determined by the following methods.

Drop test: This method is the simplest way to determine the finishing point of jam, commonly used by housewives where no other facilities are available. In this method, a little quantity of jam is taken from the boiling pan in a tea spoon and allowed to air cool before putting a drop of it in a glass filled with water. Settling down of the drop without disintegration denotes the end point (Figure 10.1).

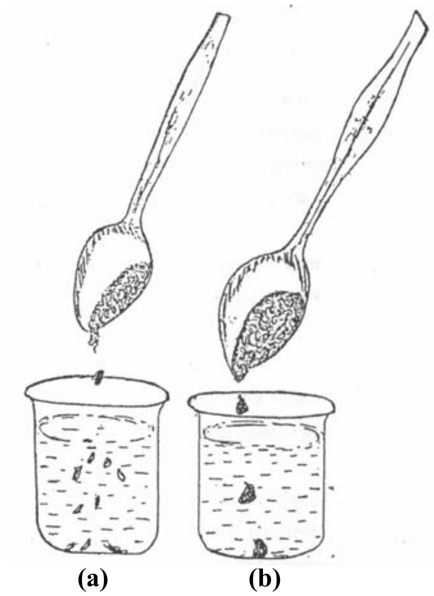
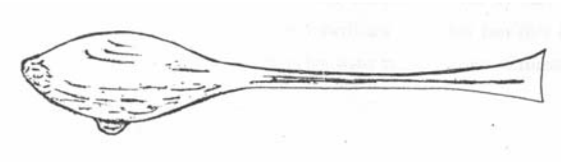
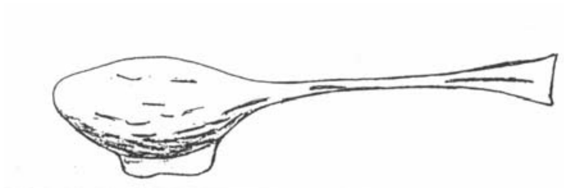


Figure 10.1: Determination of end point of jam/jelly drop test. a) Unfinished; b) End point

By sheet test: In this test, a small portion of jam is taken with a large spoon or wooden ladle, cooled slightly and then allow to drop off keeping the spoon or ladle in horizontally inclined position. If the jam drops like syrup, further concentration is needed. If it is in the form of flake or forms a sheet, the finishing point is attained (Figure 10.2).



(a)



(b)

Figure 10.2: Determination of end point of jam/jelly sheet test. a) Unfinished; b) End point

Refractometer method: This is the most common method used by small and large scale fruit processing industries for jam making (Figure 10.3). The cooking is stopped when the refractometer shows 69 ^{o}Brix.

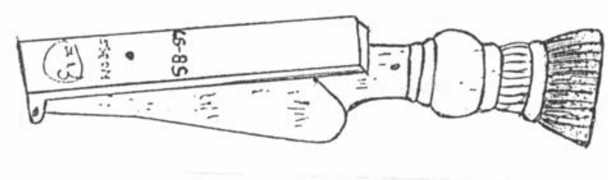


Figure 10.3: Refractometer

Boiling point method: Jam containing 69% TSS boils at 106 ^{o}C at sea level. This method is simplest and best to determine the finishing point of jam.

By weighing method: Weighing method is more laborious and time consuming. Here the boiling pan is weighed before and again after transferring the extract and sugar in to it. The end point is attained when the net jam weight is one and a half times of the quantity of sugar added.

10.3.3 Packaging

The product is packed in cans or glass jars, and cooled, followed by labelling and packaging. Containers including can or jar gets sterilized when hot jam (not less than 85^{o}C) is poured in them. Boiling the containers in hot water can also effect sterilization.

10.3.4 Special Care/ Problems in Jam Production

Crystallization: The final product should contain 30–40% invert sugar. If the percentage is less than 30, cane sugar may crystallize out on storage and if it is more than 50 the jam will become a honey-like mass due to high inversion of sugar into glucose. Corn syrup or glucose may be added along with cane sugar to avoid crystallization.

Sticky or gummy jam: Because of high percentage of total soluble solids, jams tend to become gummy or sticky. This problem can be solved by addition of pectin or citric acid, or both.

Premature setting: This is due to low total soluble solids and high pectin content in the jam and can be prevented by adding more sugar. If this cannot be done a small quantity of sodium bicarbonate is added to reduce the acidity and thus prevent pre-coagulation.

Surface graining and shrinkage: This is caused by evaporation of moisture during storage of jam. Storing in a cool place can reduce it.

Microbial spoilage: The mould attack on jam can be eliminated by storing them at less than 90% RH (Preferably at 80% RH). It is also advisable to add 40 ppm sulphur dioxide in the form of KMS. In the case of cans, sulphur dioxide should not be added to the jam as it causes blackening of the internal surface of the can.

10.4 FRUIT JELLY

A jelly is a semisolid product prepared by boiling a clear, strained solution of pectin containing fruit extract, free from pulp, after addition of sugar and acid. A perfect jelly should be transparent, well set, but not too stiff, and should have the original flavour of the fruit. It should be of attractive colour and keep its shape when removed from the mould. It should be firm enough to retain a sharp edge but tender enough to quiver when pressed. It should not be gummy, sticky, or syrupy or have crystallized sugar. The product should be free from dullness with little or no syneresis, and neither tough nor rubbery.

10.4.1 Preparation of Jelly

Jellies are gellified products obtained by boiling fruit juices with sugar, with or without the addition of pectin and food acids. Jellies are usually manufactured from juices obtained from a single fruit species only, obtained by boiling in order to extract as much soluble pectin as possible.
Selection of fruits: Guava, sour apple, plum, papaya, certain varieties of banana and gooseberry are generally used for preparation of jelly. Other fruits can also be used but only after addition of pectin powder, since these fruits are low in pectin content. Fruits can be divided into four groups according to their pectin contents. This classification is highly useful in preparation of jelly, because pectin is the important component, which is responsible for the texture of the jelly. The classification is as follows.

- Rich in pectin and acid: sour apple, grape, lemon, sour oranges, jamun, sour plum.
- Rich in pectin but low in acid: apple, unripe banana, pear, ripe guava, etc.
- Low in pectin but rich in acid: sour apricot, sweet cherry, sour peach, pineapple and strawberry.

- Low in pectin and acid: ripe apricot, peach, pomegranate, strawberry and any other overripe fruit.

Extraction of pectin/boiling: After selection, the fruits are washed thoroughly as with jam preparation discussed earlier. Most of the fruits are boiled for extraction of the juice in order to obtain maximum yield of juice and pectin. Boiling converts protopectin into pectin and softens fruit tissues. Very juicy fruits do not require the addition of water and are crushed and heated to boiling only for 5 min. Firm fruits are cut or crushed and boiled with water for 5 min. The length of boiling will vary according to the type and texture of fruit. The amount of water added to the fruit must be sufficient to give a high yield of pectin e.g. apples require one half to an equal volume of water, where as citrus fruits require 2-3 volumes of water for each volume of sliced fruits.

Straining and clarification: Pectin extract is obtained by straining the boiled fruit mass through bags made of linen, flannel, or cheese cloth folded several times. For large scale production, the fruit extract is made to pass through filter presses for clarity.

Analysis of extract: Clarified extract is analysed for pH, acidity, soluble solids and pectin content by common laboratory methods. For determining pectin content the easiest way adopted is precipitating the pectin with alcohol. A rapid test for evaluation of juice pectin content is by mixing a small sample of juice with an equal volume of 96% alcohol in a tube. The mixture from the tube is then emptied on a plate. The appearance of a compact gelatinous precipitate indicates a sufficient pectin content for jellification (Figure 10.4). Insufficient pectin will remain in numerous small granular lumps.

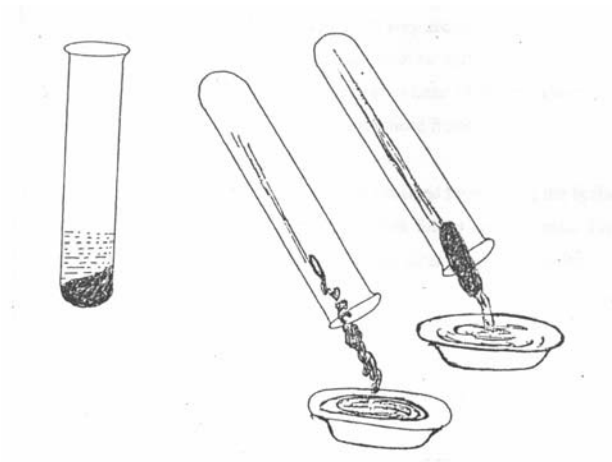


Figure 10.4: Pectin test for jelly extract. a) Low pectin extract; b) High pectin extract

Addition of sugar and pectin: Based on the pectin test of the fruit extract, quantity of sugar to be added is worked out. For the extract rich in pectin, sugar equal to the quantity of the extract is added. To the extract with moderate pectin 650 – 750 g of sugar should be added to each kg of extract. For juices rich in pectin, jellification will occur without pectin addition. If pectin content is less, 1-2% powder pectin will be added to the juice.

Addition of acid: Jelly strength increases with increasing hydrogen ion concentration until an optimum pH is reached which is generally 3.2 at 65%

sugar concentration. Jellying strength depends on the quantity of pectin and the acid present in the original fruit extract.

Processing/boiling: The juice is boiled up to remove about half of the water that has to be evaporated. Then the calculated sugar quantity is added gradually. The remainder of the water is evaporated until a TSS (refractometric extract) of 65% is reached. During boiling it is necessary to remove foam / scum formed. Product acidity must be brought to about 1% (malic acid) corresponding to pH > 3. Any acid addition is performed always at the end of boiling. Boiling of jellies is performed in small batches (25-75 kg) in order to avoid excessively long boiling time which brings about pectin degradation.

10.4.2 Judging of End Point

Boiling of jelly should not be prolonged, because excessive boiling results in greater inversion of sugar and destruction of pectin. The end point can be judged by sheet test, drop test, refractometry, thermometer, and by weighing the boiling mass. Methods like sheet test, drop test, and weighing of the boiling mass can be done in the similar way as in the case of jam preparation.

Refractometer method: This is the most common method used in fruit processing industries for jelly making. The cooking is stopped when the refractometer shows 65^o Brix.

Temperature test: A solution containing 65% TSS boils at 105^oC. Heating of the jelly to this temperature would automatically bring the concentration of solids to 65%. Endpoint of finishing jelly should be 4.5-5^oC higher than that of the boiling point of water at that place.

10.4.3 Packaging

After jelly is ready, it is skimmed to remove foam. It is cooled slightly before pouring into dry and hot glass jars. Cooling is optional and is carried out up to 85^oC, in double wall baths with water circulation. Filling is performed at a temperature not below 85^oC in receptacles (glass jars, etc.), which must be maintained still for about 24 hours to allow cooling and product jellification.

10.4.4 Important Considerations in Jelly Making

Pectin, acid, sugar (65%), and water are the four essential ingredients in jelly. Pectin test and determination of end point of jelly formation are very important for the quality of jelly.

Pectin: Pectin is the most important constituent of jelly. Stiffness of the gel increases with increasing concentration of pectin up to a certain point beyond which the addition of more pectin has little effect. Too little pectin gives a soft syrup instead of gel. Pectin tends to keep the sugar from crystallizing by acting as a protective colloid, but is not effective when the concentration of sugar is 70% or more. The amount of pectin extracted varies with the method of extraction, the ripeness of the fruit, the quantity of the water added for extracting the juice and the kind of fruit. Usually about 0.5-1.0 % of pectin in the extract is sufficient to produce good jelly. If the pectin content is higher a firm and tough jelly is formed and if it is less the jelly may fail to set.

Acid: The jellying of extract depends on the amount of acid and pectin present in the fruit. Tartaric acid gives a better result compared to citric and malic acid. The final jelly should contain at least 0.5% but not more than 1% total acid. Higher percentage of acid may cause syneresis of jelly.

Sugar: This is an essential constituent of jelly, which imparts to it sweetness as well as body. If the concentration of the sugar is high, the jelly retains less water resulting in a stiff jelly. When sugar is boiled with an acid it is hydrolysed into dextrose and fructose. Because of this partial inversion of the sucrose, a mixture of sucrose, glucose and fructose are found in the jelly. This mixture is more soluble in water than sucrose alone and hence the jelly can hold more sugar in solution without crystallization.

10.4.5 Problems in Jelly Making

The most important difficulties that are experienced are as follows:

- ***Failure to set:*** This may be due to the addition of too much sugar, lack of acid or pectin, cooking below/ beyond the end-point.
- ***Colour changes:*** Darkening at the top of the jars can be caused by storing them in too warm place or by an imperfect jar seal.
- ***Gummy jelly:*** It is the result of prolonged or over cooking in which more than desired inversion of sugar occurs
- ***Stiff jelly:*** Over cooking or using too much pectin makes too tough jelly which fails to spread when applied on bread.
- ***Cloudy or foggy jellies:*** It is due to the use of non-clarified juice or extract, use of immature fruits, over-cooking, over-cooling, non-removal of scum, faulty pouring, and premature gelation.
- ***Formation of crystals:*** It is due to addition of excess sugar and also due to the over-concentration of jelly. This excess sugar comes from over cooking, too little acid or from under cooking.
- ***Syneresis or weeping of jelly:*** The phenomenon of exudation of fluid from a gel is called syneresis or weeping and is caused by several factors. The factors include; excess of acid, too low concentration of sugar, insufficient pectin, premature gelation, and fermentation
- ***Presence of mold:*** Due to imperfect sealing and insufficient sugar.
- ***Colour fading:*** This is due to high temperature and bright light in storage room. Another possible cause could be the insufficient processing to destroy the enzymes affecting colour or the elevated processing temperature, which might cause colour fading. Trapped air bubbles can also contribute to the chemical changes by oxidation.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are the problems in jam preparation?

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2. How will you judge the end point of a jelly?

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10.5 MARMALADE

This is fruit jelly in which slices of the fruit or its peel are suspended. The term is generally used for products made from citrus fruits like oranges and lemons in which shredded peel is used as the suspended material. In the preparation of marmalade, pectin and acid contents are kept on higher side than jelly. Bitterness is regarded as desirable characteristic of product. Marmalades are classified into two: jelly marmalade and jam marmalade.

10.5.1 Jelly Marmalade

Good quality jelly marmalade can be prepared from a combination of Sweet orange/ Mandarin orange and sour orange in a 2:1 proportion. Shreds of sweet orange (Malta) peel are used in the preparation.

10.5.2 Preparation of Jelly Marmalade

Sound, ripened fruit is sorted, washed, and prepared. The mode of preparation varies with the nature of the fruit. The fruits are then cut in to slices and are boiled for the preparation of extract.

Preparation of extract: The extraction of pectin, filtration/ straining of the extract and analysis of the extract is carried out in the same way as that of jelly preparation. This is explained under the headings 2.4.1.

Preparation of peel shreds: The outer layer of yellow portion of citrus fruits is peeled off carefully. The stripped-off peel is cut into slices of about 2-2.5 cm long and 1-1.2 mm thick. Boiling in water with 0.25% sodium bicarbonate or 0.1% ammonia solution can soften the shreds. Before addition to the jelly, the shreds may be kept in heavy syrup for some time to increase their bulk density to avoid floating on the surface when it is mixed with jelly.

Boiling: The fruit extract is boiled before the addition of sugar. During boiling, the impurities in the form of scum, are occasionally removed. When the temperature of the mixture reaches 103°C, the prepared shreds of peel are mixed in it at the rate of 5-7% of the original extract. Boiling is continued till the end point is reached. The end point is judged in the same way as in the case of jelly. Like jelly, marmalade also contains 65% TSS at 105°C. Boiling should not prolong for more than 20 min, after the addition of sugar to get bright and sparkling marmalade.

Cooling: The marmalade is cooled to permit the absorption of sugar by the shreds from the surrounding syrup. If the marmalade is filled in hot, the shreds may come to the surface instead of remaining in suspension. During cooling, the product is gently stirred occasionally for uniform distribution of shreds. When marmalade temperature reaches around 85°C, viscosity of syrup increases and a thin film begins to form on surface, which prevents shreds from coming to surface.

Flavouring: This is done by adding some flavour or orange oil to the product near the end of boiling to supplement the flavour lost during boiling. Generally, a few drops of orange oil are mixed in marmalade before filling into containers.

Packaging and Storage: Like jams and jellies, marmalade is also filled into jars and cans at a temperature around 85°C. Storage of marmalade must be done in dry rooms (relative humidity at about 75%), well ventilated, medium cool places (temperature 10-20°C), disinfected and away from direct sunlight and heat. These measures are necessary because marmalade is a hydroscopic product and, by water absorption, favourable conditions for mould development are created.

10.5.3 Jam Marmalade

Jam marmalade is practically made by the method used for preparation of jelly marmalade except that the pectin extract is not clarified. The orange peel after removing albedo portion is sliced into 0.3 cm thick pieces and treated in the same way as recommended for jelly marmalade. The sliced fruit of orange, lemon, or grape fruit after removing peel is mixed with little quantity of water and boiled to soften. The boiled mixture is pressed through coarse pulper to remove seed and to get thick pulp. The pulp is mixed with equal quantity of sugar and cooked to a consistency of 65° Brix or consistency of jam. The treated shreds are mixed in the jam when it is slightly cool. Some orange oil is also mixed in the marmalade before filling into containers. Filling and packaging is done in the similar way as adopted for packaging of jelly and jelly marmalade.

10.5.4 Problems in Marmalade Making

Browning during storage is very common which can be prevented by the addition of 0.09g of potassium metabisulphite (KMS) per kg of marmalade and not using tin containers. KMS dissolved in a small quantity of water is added to the marmalade while it is cooling. KMS also eliminates the possibility of spoilage due to moulds.

10.6 PRESERVES

A mature fruit/ vegetable or its piece impregnated with heavy sugar syrup till it becomes tender and transparent is known as preserve. When fruits are placed in a concentrated sugar syrup, the water moves out of the fruit and sugar moves into it until equilibrium is reached by osmosis. Apple, Cherry, anola, pineapple, pear, mango, papaya, strawberry, etc., can be used for making preserves. FPO specifications for preserves are given in Quality section (2.14).

10.6.1 Preparation Methods

Preparation involves primary operations like, selection of fruits, peeling, puncturing (to promote sugar penetration) and blanching. Blanching may be done with or without addictives to inactivate natural enzymes and to reduce the oxidative discolourisation. The blanched fruits are then treated for firming the texture of product. Now, sugar is added concentrated, and packed after the addition of preservatives. Different processes employed for the preparation of preserves from fruits and vegetables at commercial level are explained below.

Rapid process: Fruits are cooked in a low sugar syrup. Boiling is continued with gentle heating until the syrup becomes sufficiently thick. Rapid boiling should be avoided as it makes the fruit tough. The final concentration of sugar should not be less than 68 % which corresponds to a boiling point of 106 ^{o}C. This is simple and cheap process but the flavour and colour of the product are lost considerably during boiling.

Slow process: In this method, the fruits are blanched until it becomes tender. Sugar, equal to the weight of fruit, is then added to the fruit in alternate layers and the mixture allowed to stand for 24 hours. Then by boiling on second, third, and 4th day consecutively the strength of syrup is raised to 70 % TSS. A small quantity of citric or tartaric acid is also added to invert a portion of the cane sugar and thus prevent crystallization. The prepared preserve is then packed in containers.

Vacuum process: The fruit is first softened by boiling and then placed in the syrup which should have 30-35% TSS. The fruit syrup blend is then transferred to a vacuum pan and concentrated under reduced pressure to 70 % TSS. Preserves made by this process retain the flavour and colour of fruit better than by the other two methods.

Packaging of preserve: The preserve is cooled quickly, drained free of syrup and then filled in dry containers. Freshly prepared boiling syrup containing 68% TSS is then poured into the jars/containers which are then sealed air tight. In commercial scale production, however, it is better to sterilize the cans to eliminate any possibility of spoilage of product during storage.

10.7 CANDIED FRUIT/ VEGETABLE

A fruit or vegetable impregnated with cane sugar or glucose syrup, and subsequently drained free of syrup and dried, is known as candied fruit/vegetable. The most suitable fruits for candying are pineapple, cherry, anola, karonda, papaya, apple, peach, peels of orange, ginger etc.

Preparation: The process for making candied fruit is practically similar to that for preserves. The only difference is that the fruit is impregnated with syrup having a higher percentage of sugar or glucose. A certain amount (25-30 %) of invert sugar or glucose is substituted for cane sugar. The total sugar content of the impregnated fruit is kept at about 75% to prevent fermentation. It is desirable that cane sugar and invert sugar in the final syrup should be in equal proportion approximately. The syrup left over from the candying process can be used for candying another batch of the same kind of fruit.

Draining and drying: The fruit removed from the syrup is drained for about half an hour and unwanted pieces are removed. The fruit or peel is then wiped with a wet sponge or dipped for a moment in boiling water to remove adhering syrup. Then it is dried in shade or in a dryer at about 66^{o}C for 8 to 10 hours until the fruit is no longer sticky to handle.

10.8 GLAZED FRUIT/ VEGETABLE

Covering of candied fruits /vegetables with a thin transparent coating of sugar, which imparts them a glossy appearance is known as glazing. The FPO specifications for glazed fruits are given in quality section.

Preparation: Glazed fruits are prepared by passing the dried candid fruit through a sugar syrup. The sugar syrup is prepared by boiling a mixture of cane sugar and water (2:1) in a steam pan at 113 to 114 ^{o}C and skimming the impurities as they come up. Heating is then stopped and syrup is cooled to 93^{o}C. Granulation of sugar is achieved by rubbing the syrup with a wooden ladle on the side of the pan. Granulated candies are then placed on trays in warm dry room. To hasten the process, fruits may be dried in a dryer at 49^{o}C for 2 to 3 hours till they become crisp. These are then packed in air tight containers for storage.

10.9 CRYSTALLIZED FRUITS/ VEGETABLES

Candied fruits/ vegetables when covered or coated with crystals of sugar, either by rolling in finely powdered sugar or by allowing sugar crystals to deposit on them from a dense syrup are called crystallized fruits.

Preparation: The candied fruits are placed on a wire mesh tray which is placed in a deep vessel. Cooled syrup (70% TSS) is gently poured over the fruit so as to cover it entirely. The whole mass is left undisturbed for 12 to 18 hours during which time a thin coating of crystallized sugar is formed. The tray is then taken out carefully from the vessel and the surplus syrup drained off. The fruits are then placed in a single layer on a wire mesh trays and dried at room temperature or at about 49 ^oC in dryers.

10.10 FRUITS BAR/LEATHER

Fruit bar or leather can be prepared from different fruit pulps like mango, peach, plum, apricot, papaya, etc. The fruit pulp is taken and its TSS is raised to 30 ^{o} Brix by adding sugar. This pulp is then spread on stainless steel trays smeared with glycerol which are dried in a mechanical dehydrator at 60 $\pm$ 5 ^oC for 2 hours. Usually five layers are dried one above the other and the final product is packed in polythene bags.

10.11 FRUIT TOFFEES

This is made by mixing fruit pulp with other ingredients like glucose, milk powder and edible fat. The fruit pulp is first concentrated to half its volume. Generally, for one kilo gram of concentrated pulp, 160 g of glucose, 320 g of milk powder and 200 g of edible fat is added. This mixture is further heated to a thick consistency (75- 80 ^{o}Brix) followed by spreading it as a sheet of one cm thickness on a glycerol smeared flat tray and allowed to cool. Then these are cut into pieces (called as toffees) of desired size, wrap and store it in cool dry place.

10.12 PACKAGING OF THE FINISHED PRODUCT

Since candied and crystallized fruits are hygroscopic, they require waterproof packaging. These are packed in paper cellophane cartons. But with the development of packaging technology various types of flexible films are used, which are cheaper and highly effective in controlling moisture absorption and entry of other undesirable material from outside atmosphere into the food.

10.13 PROBLEMS IN PREPARATION OF PRESERVES/ CANDID FRUITS

- **Fermentation**: It is due to the low concentration of sugar used in the initial stages of preparation.
- **Floating of fruits in jar**: It is due to filling of the preserve without cooling.
- **Toughening of fruit skin or peel**: This is due to inadequate blanching or cooking.
- **Fruit shrinkage**: This is due to cooking of fruits in heavy syrup.
- **Stickiness**: It is due to insufficient consistency of the syrup, poor quality packaging and damp storage conditions.

10.14 QUALITY PARAMETERS

Quality is a measure of the degree of excellence or degree of acceptability by the consumer. The quality characteristics of a product may be due to sensory (colour, texture and flavour), hidden (nutritive value, toxicity, etc.), and quantitative characteristics (yield of jam, jelly etc.). Food quality control is generally defined as the regulation by law of food manufacture, distribution and sale, in order to prevent health hazards and fraud to the consumer. FPO act regulates the manufacture, storage and sale of fruit and vegetable products. The details of FPO and other aspects of quality are detailed in Unit 1.

The FPO specifications includes: methods of preservation, permissible colours in the preparations and also the minimum quality requirements of the final products. FPO specifications for jam jelly, marmalade, preserve, candy and other sugar based products are as follows:

Product		**Specifications**	
		Minimum % of TSS in final product	**Minimum % of prepared fruit in final product**
1.	Fruit jam	68	45 (25% in case of strawberry jam)
2.	Fruit jelly	65	45
3.	Marmalade	65	45
4.	Fruit preserve	68	55
	Product	**Specifications**	
		Total Sugar (%)	**Reducing sugar as % of total sugar**
1.	Candied and crystallized or glazed fruit and peel	Not less than 70	Not less than 25

Permissible limits of preservatives in fruit beverages

Sl. No.	**Product**	**Preservative**	**Parts per million (ppm)**
1.	Fruit jam, jelly, marmalade and preserve	Sulfur dioxide	150
2.	Crystallized, glazed fruits (including peel)	Sulfur dioxide	150

Some important quality considerations

- Jelly made from sugar and chemical pectin shall be clearly declared as synthetic jelly.
- When dry fruit is used for making jam it shall be clearly declared on the label.
- When preserves are packed in sanitary top cans, the contents shall not be less than 85% of the total space of the can.

10.15 LET US SUM UP

You must have now well understood that the basic principle behind the preparation of sugar based products is the addition of sugar and concentrating them by evaporation to a point where microbial spoilage is arrested.

We have also seen the importance of sugar and various sweeteners and their role in processed foods like jam, jelly etc. The methods for preparation of jam, jelly, marmalade and other sugar based products are detailed in this unit. The special care taken during their preparation are also traced out. A brief note of quality standards and packaging is also included.

10.16 KEY WORDS

Artificial sweeteners	:	They are synthetic, calorie free, high intensity sugar substitutes, sometimes used in place of other sugars in food manufacturing and cooking.
Glazing	:	Coating candied fruit with a thin transparent layer of sugar, which imparts them a glossy appearance, is known as glazing.
Crystallized fruit	:	These are candied fruits covered or coated with crystals of sugar.
Jam	:	Jam is a product with reasonably thick consistency, firm enough to hold the fruit tissues in position, and is made by boiling fruit pulp with sufficient sugar.
Jelly	:	Jelly is a semi solid product prepared by boiling a clear, strained solution of pectin containing fruit extract, free from pulp, after addition of sugar and acid.
Humectancy	:	Ability to retain water.
Inversion of sugar	:	Inversion is a chemical process in which sucrose breaks down to its constituent sugars: glucose and fructose.
Marmalade	:	Marmalade is a fruit jelly in which slices of the fruit or its peel are suspended.
Preserve	:	A mature fruit or its piece impregnated with heavy sugar syrup till it becomes tender and transparent is known as preserve.

10.17 SELF TEST FOR THE COMPLETE UNIT/ ASSIGNMENT

1. List out the various types of sugars.

2. How is marmalade different from jelly?

3. What is preserve? Why vacuum process is better compared to rapid and slow process?

4. What is a glazing? How it is different from crystallized fruit?

10.18 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. The various functional properties of sugar in food system include: source of energy, nutritional aspects, flavour and colour production, sweetening, texturing, plasticizing action and humectancy. Sugars provide readily accessible fuel for physical performance.

2. Sugar alcohols or polyols are slightly lower in calories than sugar and do not cause a sudden increase in blood glucose. Polyols are sweet and can be used in foods in a similar way to sugars although they can have a laxative effect when eaten in large quantities. Commercially they are made by the transforming sugars and are used mainly to sweeten sugar-free candies, cookies, and chewing gums. Eg: sorbitol, and mannitol.

3. Artificial sweeteners are non-nutritive or calorie free, high intensity sugar substitutes. These are sweet synthetic substances, often used in place of other sugars in food manufacturing and cooking. Eg: aspartame and saccharin.

Check Your Progress Exercise 2

1. The various problems encountered in the production of jam includes: Crystallization: due to the lower percentage of invert sugar(<30 %), Sticky or gummy jam: due to high percentage of TSS, Premature setting: due to low TSS and high pectin content, Surface graining and shrinkage: caused by evaporation of moisture and microbial spoilage during storage.

2. The end point of jelly can be judged by sheet test, drop test, refractometry, thermometer, and by weighing the boiling mass. Refractometer method is the most common method used in fruit processing industries for jelly making. The cooking is stopped when the refractometer shows 65 ^{o}Brix.

Answers to Assignments

1. Various types of sugars are available for different food preparations. They are Granulated Sugar, Brown Sugars and Liquid Sugars. Granulated sugar includes: Regular sugar, Fruit Sugar, Bakers Special, Superfine, Ultra -fine, Bar Sugar, Confectioners Sugar, Coarse Sugar, Sanding Sugar, where as Brown Sugars includes: Free Flowing Brown Sugars and Caramelized Sugar. The Liquid Sugars includes Liquid Sugar syrup and invert Sugar.

2. Marmalade is a fruit jelly in which slices of the fruit or its peel are suspended. The term is generally used for products made from citrus fruits like oranges and lemons in which shredded peel is used as the suspended

material. In the preparation of marmalade, pectin and acid contents are kept on higher side than jelly.

3. A mature fruit/ vegetable or its piece impregnated with heavy sugar syrup till it becomes tender and transparent is known as preserve. Since the concentration process is done under vacuum, i.e., at low temperature, the flavour and colour retention will be more in vacuum process. Where as the same will be lost at higher operating temperature in rapid and slow process.

4. Covering of candied fruits /vegetables with a thin transparent coating of sugar, which imparts them a glossy appearance is known as glazing. Where as crystallized fruits are candied fruits/ vegetables covered or coated with crystals of sugar, either by rolling in finely powdered sugar or by allowing sugar crystals to deposit on them from a dense syrup.

10.19 SOME USEFUL BOOKS

1. Girdhari Lal, Siddappa, G.S. and Tandon, G.L. (1995) Preservation of Fruits and Vegetables, ICAR, New Delhi.

2. Sivasankar, B. (2002) Food Processing and preservation, Prentice–Hall of India Pvt. Ltd., New Delhi- 110 001.

3. Verma, L.R. and Joshi, V.K. (2000) Post harvest Technology of Fruits and Vegetables: Handling, processing, fermentation and Waste management, Volume-1, General Concepts and principles, Indus Publishing company, New Delhi.

UNIT 11 PICKLES, CHUTNEYS, SAUCES AND TOMATO PRODUCTS

Structure

11.0 OBJECTIVES

By the time you have studied this unit, you should be able to describe:

- various methods of pickling and their keeping quality;
- preparation of chutney and sauces;

- preparation of various tomato products viz., Tomato Juice, Tomato Puree, Tomato Paste, Tomato Cocktail, Tomato Ketchup, Tomato Sauce, Tomato Soup; and
- quality standards, packaging and storage aspects of finished products.

11.1 INTRODUCTION

In the previous unit, you have learnt about the sugar based products from fruits and vegetables. Now we will see the preservation technique using salt, vinegar, spices, oil etc. Pickles, chutney and sauces are pleasant preserves of mainly fruits and vegetables and are good accompaniment of Indian as well as continental foods. These products improve the taste of food, stimulate the appetite and enhance digestion. Besides providing the diet with a variety, these products also make a nutritional contribution to the food and save time in a busy household schedule.

In this unit, we will study the pickling by different methods, their shelf life and causes of spoilage. An attempt has also been made to illustrate the different processing methods of chutney and sauces. Detailed processing steps of various tomato products and the quality aspects of the finished products are also included.

11.2 PICKLES

Pickle is an edible product preserved in a solution of common salt and vinegar. It is one of the most ancient method of preserving fruits and vegetables. Pickles are good appetizers and add to the palatability of meal. They stimulate the flow of gastric juice and thus help in digestion. Several kinds of pickles are sold in Indian market. Mango pickle ranks first. Pickles can also be prepared from fruits and vegetables like lemon, amla, onion, cauliflower, cabbage, beans, cucumber, bitter gourd, jackfruit, turnip etc. These are commonly made in homes as well as commercially prepared and exported. Fruits are generally preserved in sweetened and spiced vinegar, while vegetables in salt.

11.2.1 Pickling Process

The preservation of food in common salt or in vinegar is called pickling. Pickling may also be the result of fermentation by lactic acid forming bacteria, which are naturally present in large numbers on the surface of fresh vegetables and fruits. These bacteria can grow in acid medium and in the presence of 8-10% salt solution, whereas the growth of majority of undesirable organisms is inhibited. Lactic acid bacteria are most active at 30^{o}C, so this temperature should be maintained, as far as possible, in the process of pickling. Pickling is done in two stages.

Stage I can be done by any of the three following methods:

i) Fermentation with dry salting,
ii) Fermentation in brine, or
iii) Salting without fermentation.

Stage II is finishing and packing.

11.2.2 Fermentation with Dry Salting

In this method, the vegetable is treated with dry salt. The salt extracts the juice from the vegetables and forms the brine, which is fermented by lactic acid bacteria. The method of dry salting in general is as follows:

The vegetable is washed, drained, weighed for preparing pickles. Several alternate layers of the prepared vegetable and salt (20-30 g of dry salt/ kg vegetables) are kept in a vessel which is covered with a cloth and a wooden board and allowed to stand for 24 hrs. During this period brine is formed by osmosis. As soon as the brine is formed, the fermentation process starts and the CO_2 begins to evolve. When fermentation is over, gas formation stops. Under favourable conditions fermentation is completed in 8-10 days, however in cold weather it may take 2 to 4 weeks. When sufficient lactic acid has been formed, lactic acid bacteria stops to grow and no further change takes place in vegetables. However, precaution should be taken against spoilage by aerobic microbes, because in the presence of air "pickles scum", a kind of wild yeast, is formed which brings about putrefaction and destroys the lactic acid. Therefore the product may be preserved and kept by excluding air.

11.2.3 Fermentation in Brine

Steeping of the vegetables in a salt solution of pre determined concentration for a certain length of time is called brining. When vegetables are placed in brine, it penetrates in the tissues of the vegetables and soluble material present in vegetable diffuses into the brine by osmosis. The soluble material includes fermentable sugars and minerals. The sugars serve as food for lactic acid bacteria, which convert them into lactic and other acids. The acid brine thus formed acts upon vegetable tissues to produce characteristic taste and aroma of pickle.

The amount of brine required is usually half the volume of vegetables. Brining is the most important step in pickling. The growth of the majority of spoilage organisms is inhibited by brine containing 15% salt. Lactic acid bacteria, which are salt-tolerant, can thrive in brine of 8-10% strength though fermentation takes place fairly well even in 5 % brine. In a brine containing 10 % salt, fermentation proceeds somewhat slowly. Fermentation takes place to some extent up to 15 % but stops at 20% brine strength. It is, therefore, advisable to place the vegetables in 10 % salt solution for vigorous lactic acid fermentation. After fermentation process, the salt content is now increased gradually, so that by the time pickle is ready, salt concentration reaches 15%.

11.2.4 Salting Without Fermentation

Vegetables are washed, prepared and is mixed with salt (250 g/kg of prepared material). This high salt concentration will inhibit the fermentation. Vegetables packed with large amount of salt get cured. Then, they are drained and excess of salt is removed by soaking them in cold or warm water. Thereafter, the vegetables are stored in plain vinegar of 10% strength for several weeks. Vegetables can also be stored in sweetened and spiced vinegar. The spices can be added in the ground form or essential oil of spices may be added to impart the spice flavour.

11.3 VARIOUS PICKLES

At present, pickles are prepared with salt, vinegar, oil or with a combination of above ingredients with spices. These methods are discussed below:

11.3.1 Preservation with Salt

Salt improves the taste and flavour and hardens the tissue of vegetables and controls fermentation. Salt content of 15% or above prevents microbial spoilage. This method of preservation is generally used only for vegetables, which contains very little sugar. Since the sugar content is less, sufficient lactic acid cannot be formed by fermentation to act as preservative. However, some fruits viz., mango, lemon, etc. are also preserved with salt. An example for pickle preparation with salt is shown in Figure 11.1.

Mangoes (Matured green)
↓
Washing
↓
Peeling
↓
Slicing
↓
Putting slices in jar
↓
Sprinkling salt
↓
Putting in sun for one week
(shaking jar at least twice a day to mix the salt)
↓
Mixing spices
↓
Storage at ambient temperature
(In cool dry place)

Figure 11.1: Flow chart of mango pickle

11.3.2 Preservation with Vinegar

This technology is based on the addition of food grade vinegar which has a bacteriostatic action in concentrations up to 4% acetic acid and bactericidal action in higher concentrations. Vegetables preserved in vinegar need to reach a final concentration of 2-3% acetic acid in order to assure their preservation. To achieve this final concentration, a 6-9% acetic acid vinegar is used, as related to the specific ratio of vinegar: vegetable. This higher concentration treatment helps to expel the gases present in the intercellular spaces of vegetable tissue.

In vinegar pickles, salt (2-3%) and sometimes sugar (2-5%) are also added. If the vinegar concentration is lower than 2%, vinegar pickles need to be submitted to a pasteurization in order to assure their preservation. Mango, garlic, chilies, etc. are preserved as such in vinegar. Vinegar pickles are the most important pickles consumed in other countries. Figure 11.2 shows the schematic flow chart of onion pickle by using vinegar as preservative.

Onion (small)
↓
Peeling
↓
Blanching for 5 minutes
↓
Filling blanched onions in jar
↓
Addition of salt
↓
Keeping for 1-2 days
↓
Draining off water
↓
Addition of vinegar and Spices
↓
Storage

Figure 11.2: Flow chart of onion pickle

11.3.3 Preservation with Oil

Oil pickles are highly popular in India. They are highly spiced. In India, mustard oil, rapeseed oil, sesame oil are generally used. The fruits or vegetables should be completely immersed in the edible oil. Cauliflower, lime, mango and turnip pickles are the most important oil pickles. The pickle remains in good condition for one to two years if handled properly. A schematic flow chart of lemon pickle by using oil as preservative is shown in Figure 11.3.

Lemon
↓
Washing
↓
Cutting into 4 pieces
↓
Squeezing out juice from $1/4^{th}$ amount of fruit
↓
Mixing spices and salt with juice
↓
Mixing with pieces
↓
Filling in jar
↓
Keeping in sun for 4-6 days
↓
Addition of oil after heating
↓
Cooling it
↓
Storage

Figure 11.3: Flow chart of lemon pickle

11.3.4 Preservation with Salt, Vinegar, Oil and Spices

This method combines the advantages of fermentation action of salt and the preservation action of both vinegar and oil. The flavouring property of spices is also made use of. The spices are usually fried in oil and mixed to the prepared fruit/ vegetable before the addition of vinegar. The spices can be added separately or in the form of spice vinegar. A schematic flow chart of tomato pickle by using salt, vinegar, oil and spices as preservative is shown in Figure 11.4.

Tomatoes
↓
Washing
↓
Blanching for 5 minutes
↓
Cooling immediately in water
↓
Peeling & Cutting into 4-6pieces
↓
Frying all ingredients in a little oil (except vinegar)
↓
Mixing with pieces
↓
Heating for 2 minutes & Cooling
↓
Addition of vinegar & remaining oil
↓
Filling in jars & storage

Figure 11.4: Flow chart of tomato pickle

11.4 CONTAINERS USED FOR PICKLING

Metallic vessels should be non corrodible. Usually, wide mouthed jars are used as they are easy to clean. The container should not impart any colour, taste, and flavour of its own to the pickle. Glass vessels, stainless steel, monel metal and aluminum containers are generally used as cooking utensils. The ladles, spoons and measuring vessels should also be of non corrosive materials.

11.5 KEEPING QUALITY

Properly brined vegetables will keep well in vinegar for a long time. The duration of brining is of utmost importance. If the vegetables are soaked for a short time of about 12 hrs only, the curing of the vegetable tissues will be incomplete with the result that the pickle will not have proper texture and taste. Brining has, therefore, to be controlled properly. On curing, the vegetables becomes semi translucent, and their colour changes from green to dark olive green or yellowish green. This is an indication of correct curing. This usually takes 4-5 weeks. By this method the vegetables can be kept more or less for an indefinite period, provided the right storage conditions are maintained. If the vegetable is kept in brine of 10% or less, all air should be excluded from the containers. During curing, the vegetables lose their 'raw' flavour and become firm and crisp.

Shelf life of fermented products: Some vegetables can be stored for years in high concentration of salt solution without a serious loss in quality though they are not stored for more than a year normally. The brine fermented products can be further processed with or without mild heat processing. During fermentation in bulk containers, microbial action influences the shelf stability. Complete conversion of fermentable carbohydrate to lactic acid and other end products renders the packaged products stable to subsequent fermentation. This is due to the presence of residual sugar, which leads to gas pressure and brine turbidity in the final package as a result of yeast and lactic acid bacterial growth. Preservatives like sodium benzoate, benzoic acid, sorbic acid and potassium bi-sulphate may be added to the product to enhance the keeping quality. Microorganisms (e.g. mould) producing softening enzymes should be excluded as they are active at pH values at which the packaged products are held.

11.6 CAUSES OF SPOILAGE

Different kinds of spoilage occur in pickles. They are as follows:

Bitterness: Use of strong vinegar or excess spice or prolonged cooking of spices imparts a bitter taste to the pickle.

Blackening: This is caused by iron which enters through the brine or from the equipment. Some times specific organisms also cause blackening.

Blemishes in pickled onions: Blemishes may sometime occur in the pickles and especially in onion pickles in vinegar. In the case of onions, white blotch is sometimes seen under the first layer of the skin. This appears to be owing either to some kind of fermentation or non removal of all the brine prior to the final pickling of the cured onion in the vinegar.

Cloudiness: When vegetables are placed in vinegar, it is generally presumed that the products will not spoil. In the case of onion and some other vegetables, however, sometimes the vinegar become cloudy turbid, there by spoiling the appearance of the pack. These raw materials being of a very solid structure, the acetic acid in the vinegar may not penetrate deep enough to prevent the activity of bacteria or other microbes that may be present in them . Hence the fermentation stars from inside rendering the vinegar cloudy. This activity of microbes can only be checked by proper brining. Cloudiness may also be caused by the use of a vinegar of inferior quality or imitation vinegar, or possibly by chemical action between the vinegar and the impurities such as calcium, magnesium and iron compounds that may be present in the salt used. This may also be caused by the reaction between the vinegar and minerals naturally present in the vegetable itself.

Dull and faded product: This is due to use of inferior quality materials or insufficient curing.

Scum formation: When vegetables are placed in the brine for curing a white scum is invariably formed on the surface owing to the growth of wild yeast. This scum may be thin or thick in appearance, varying from an almost imperceptible film to a thick wrinkled layer. It retards the formation of lactic acid. As this action may help in the growth of putrefactive bacteria, which causes the vegetable to become soft and slippery, it is essential to remove the scum as soon as it is formed. Addition of about 1% acetic acid helps to prevent the growth of wild yeast on the brine, without in any way hindering the formation of lactic acid. For this reason some manufacturers add a small amount of vinegar to the brine in the initial stage.

Shrivelling: This occurs when vegetables (e.g. cucumber) are placed directly in a very strong solution of salt or sugar or vinegar, Hence, a dilute solution should be used initially and its strength gradually increased.

Softness and slipperiness: This is the most common form of spoilage and caused by the action of bacteria. It is invariably owing to inadequate covering with brine or owing to the use of a week brine. By using a brine of proper strength and by keeping the pickle well below the surface of the brine, this kind of spoilage can be eliminated.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the principle of pickling?

……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………

2. What is the need for a higher initial vinegar concentration in vinegar pickling?

……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………

3. What are the causes of pickle spoilage?

……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………

11.7 CHUTNEYS

A chutney is basically a mixture containing fruit or vegetable, spices, salt and/ or sugar, vinegar, etc. The method of preparation is similar to that adopted in the case of jams except that spices and vinegar are added. Chutney of good quality should be reasonably smooth, palatable, appetizing and have the true single flavour of the fruit or the vegetable used for the preparation.

11.7.1 Preparation of Chutney

Ripe fruit or vegetable is selected, cut into slices or pieces of suitable size and are softened by boiling in water. These are then, slowly cooked at a temperature below boiling point. Onion and garlic are added at the start to mellow their strong flavours. Spices are coarsely powdered before they are added to the product. Whole spices, if used, are bruised and tide loosely in muslin cloth before adding to the mixture and removed before bottling. Vinegar, sugar, and spices are added just a little before the final stage of boiling. This prevents the loss of some essential oils of spices and vinegar due to volatilization.

Long cooking of sugar darkens the colour of the chutney. For the preparation of dark colour chutney brown sugar is usually preferred, where as, white sugar is preferred for white colour chutneys. Spiced vinegar gives high quality product. Chutneys usually get thickened on cooling. The chutneys are bottled, while hot, in clean and warm jars which are then, adequately sealed and sterilized. A schematic flow chart of chutney production is shown in Figure 11.5.

Fruit/Vegetable
↓
Grading for Ripeness & Freshness
↓
Washing
↓
Peeling, Slicing/Crown Removing/Coring
↓
Boiling
↓
Cooking with Onion and Garlic and/or Ginger
↓
Adding Coarsely Powdered Spices/ Spiced Vinegar & vinegar
↓
Coking till required consistency obtained
↓
Boiling hot and Sealing
↓
Sterilizing
↓
Cooling
↓
Labelling & Storage

Figure 11.5: Flow chart of chutney production

11.8 SAUCES

Sauces and chutneys are usually made from the same raw materials, spices and flavours, however, difference is that, all sauces are sieved and as a result, are thinner and of smoother consistency than chutneys. The sieving is done to remove the skin, seeds and stalks of fruits, vegetables, and spices and to give a smooth consistency. Here the cooking process is longer compared to the chutney due the use of fine pulp or juice.

Sauces are generally of two kinds, and they are the thin sauces and the thick sauces. A good sauce whether thin or thick, have a continuous flow with no skin, seeds and stalks of the fruit and/ or vegetables and spices used for its preparation, and possesses pleasant taste and aroma. The details of thin and thick sauces are given below:

11.8.1 Thin Sauces

Thin sauces mainly consist of vinegar extract of various flavouring materials like, spices and herbs. Their quality depends mostly on the piquancy of the material used. Some sauces are matured by storing them in wooden barrel or casks. During storage they develop flavour and aroma. Freshly prepared products have often a raw and strong taste and they should, therefore, be matured by storage.

Preparation: For the preparation of thin sauces of high quality, the spices, herbs, fruits, and vegetables are macerated in cold vinegar. Some times, they are also prepared by boiling them in vinegar. The sauce is filtered through a fine or coarse mesh sieve of non corrodible metal, according to the quality desired. The skin, seeds and stalks of fruits, vegetables and spices used, should not be allowed to pass through the sieve as they spoil the appearance of the sauce. The usual commercial practice is to prepare vinegar extracts of each kind of spice and fruit separately, either by maceration or by boiling in vinegar and then blending these extracts suitably before filling the sauce into barrels for subsequent maturation.

Soya sauce made from soybeans and Worcestershire sauce made from tamarind are examples of thin sauces. The Worcestershire sauce is utilized in the preparation of cocktail also. Figure:6 shows a schematic flow chart of thin sauce production.

Preparation of Thin Sauce

Fruit/Vegetable
↓
Grading for Ripeness & Freshness
↓
Washing
↓
Macerated in cold vinegar with spices & herbs
↓
Extraction of pulp
↓
Cooking with spices/spiced vinegar and Vinegar
↓
Filtering
↓
Bottling
↓
Sealing
↓
Sterilizing
↓
Cooling
↓
Labelling & Storage

Figure 11.6: Flow chart of thin sauce production

11.8.2 Thick Sauces

A sauce which does not flow freely and which is highly viscous is called a thick sauce. On the other hand thin sauces are less viscous in consistency. Thick sauces also contain more of sugar and less of acid. Generally spices and colouring added are practically similar to those in the case of thick ketchups and sauces. It should contain at least 3% acetic acid to ensure its keeping quality. The acidity should not however, exceed 3.4% as otherwise the sauce would taste sharp. The sugar content may usually varied from 15-30% according to the kind of sauce made. Usually malt vinegar is used. In addition to contributing to acidity of the sauce, it also improves its flavour. The sweetness is derived partly from dates, raisin, apple and tomato and partly from the sugar added. The colour of the sauces varies with the raw material use. Some times a little caramel is added.

Preparation: The manufacturing process is the same as for chutneys. Thickening agents are also added to prevent or retard sedimentation of solid particle in suspension in the sauce. In this country apple pulp is often used for this purpose. The starch obtained from maize, potato, arrow root, sago and rye are also used as thickening agents. Indian gum, gelatin, Irish moss, pectin and other similar substances can also be used subject to the food laws of our country. Tomato sauce and apple sauce are some of the examples for thick sauce. Preparation of tomato sauce is explained under the section 3.10.5.

11.9 SOUPS AND OTHER MIXES

Ready to serve soups such as tomato soup, mushroom soup, mixed vegetable soups, especially dried vegetable mixtures for quick preparation of soups at home, are gaining popularity in these days. Liquid soups are generally canned. They are warmed at the time of serving. The preparation and bottling of tomato soup is explained under tomato processing (3.10.8).

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between thin sauce and thick sauce.

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2. How is ketchup different from sauce?

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3. What is the percentage of sugar in sauce & ketchup? What will happen to the product if the whole quantity of sugar is added initially?

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11.10 TOMATO PRODUCTS

Tomato is grown in our country in abundance, in all seasons. The farmer will get a very low profit during the peak-harvesting season and nearly 25% of the produce is spoiled due to improper post harvest practices. Such losses can be avoided by converting tomatoes into delicious products. Tomato can be processed to a variety of products like; canned tomato, paste, puree, juice, ketchup and sauce. In India tomato sauce and ketchup are very popular and are being manufactured on an increasingly large scale.

11.10.1 Tomato Juice

This product is characterised not only by its organoleptical properties (taste, colour, flavour) but also by its vitamin content close to those of fresh tomatoes. Modern technology is oriented to a maximum maintenance of organoleptic properties and of vitamin content.

At same time, it is important to assure juice uniformity by avoiding cellulosic particle sedimentation. A good quality juice should contain about 0.4 % acid (in terms of citric acid), 0.5% salt, and 1 % sugar. Juice stability is assured by a flash pasteurization, which assures the destruction of natural micro-flora, while keeping the initial properties. The modern technological flow sheet covers the following main operations:

Preparation of Tomato Juice

Pre-washing and washing: Pre-washing is carried out by immersion in water, cold or heated up to 50°C (possibly with detergents to eliminate traces of pesticides). Then washing is performed with water sprays.

Sorting: Only sound ripe red coloured tomatoes are used for the juice preparation. This is done on rolling sorting tables. This enables the removal of non-standard tomatoes – with green parts, yellow coloured, etc.

Crushing and pulping: Crushing is carried out in a special equipment. Fluted wooden roller crushers are utilized for this purpose. The crushed tomatoes can be pulped by the hot process or by the cold process. In hot pulping, crushed tomatoes are boiled in their own juice in steam jacketed stainless steel pans or in aluminium pans for 3 to 5 minutes. This process facilitates the extraction, dissolves pectic substances and contributes to the maintaining of vitamins and natural pigments. In some modern installations, this step is carried out under vacuum at 630-680 mm Hg and in very short time. Whereas in cold pulping, the tomatoes are crushed in cold and as such passed through a pulper. Here the extraction of juice is difficult and yield will be less compared to hot process.

Extraction: Extraction of juice and part of pulp (maximum 80%) is performed in special equipment / tomato extractors with the care to avoid excessive air incorporation. In some installations, as an additional special care, a part of pulp is removed with continuous centrifugal separators.

Deaeration and Homogenization: The air from the extracted juice is removed by using a deaerator under high vacuum. Homogenization is done for mincing of pulp particles and is mandatory in order to avoid future potential product "separation" in two layers.

Filling and bottling: After flash pasteurization at 130-150°C for 8-12 second, the juice is cooled at 90°C. This cooled juice is filled in receptacles (cans or bottles) at the same temperature (90^0C). The receptacles are then closed followed by their inversion for about 5 to 7 minutes. Cooling has to be carried out intensely. Full cans do not need further pasteurization because the bacteria that have potentially contaminated the tomato juice during filling are easily destroyed at 90°C due to natural juice acidity.

For bottles, it may be possible to avoid further sterilization if the following conditions can be strictly adhered: washing and sterilizing of receptacles, cap sterilization (with formic acid), filling and capping under aseptic conditions, in a space with UV lamps. Since this is quite difficult to achieve, it may be necessary to subject the bottles for pasteurization in water baths.

11.10.2 Tomato Puree

Tomato pulp without skin or seeds, with or without added salt, and containing not less than 9.0% of salt free tomato solids is known as "Medium tomato puree". It can be concentrated further to 'heavy tomato puree', which contains not less than 12% solids.

Preparation of tomato puree: Manufacturing steps fall into three successive categories: (i) obtaining tomato juice from the raw materials; (ii) juice concentration and (iii) tomato puree pasteurization. Tomato pulp and juice extraction is done from ripe tomatoes in the same manner as tomato juice preparation.

Concentration of the pulp is carried out either in an open cooker or in a vacuum pan. In open cooking, most of the vitamins are destroyed and the product becomes brown. On the other hand, use of vacuum pans, nutritive value is preserved and browning is also reduced. However this method is quite expensive. Ordinarily tomato juice can be concentrated to lower range in an open cooker, but for obtaining higher concentrations a vacuum pan is required. The end point is judged by determining the TSS. This is done by using either a specific gravity hydrometer or by a refractometer.

Tomato puree pasteurization assures the microbiological stability of the product. For this purpose, the puree coming out from concentration equipment is passed continuously and in a "forced" mode through a tubular pasteurizer from which it emerge, at a temperature of 90-92° C. The pasteurized puree is then filled hot in to cans or in glass receptacles.

11.10.3 Tomato Paste

The product with highest production volumes among concentrated products is tomato paste, which is manufactured in a various range of concentrations, with a minimum of 25% and up to 44% refractometric extract. The product is very similar to tomato puree except that the solid concentration is more. Tomato paste is the product obtained by removal of peel and seeds from tomatoes, followed by concentration of juice by evaporation under vacuum. Good quality tomato paste is a homogenous mass, with a high density, without foreign bodies (seeds, peel, etc.), with a red colour, and an agreeable taste and smell, close to those of fresh tomatoes.

Preparation procedure is also similar to that of tomato puree. Here the tomato juice obtained is further concentrated so that it contains not less than 25% tomato solids. This is known as tomato paste. On further concentration to 33% or more of solids, it is called concentrated tomato paste. Paste of good quality must have a volatile acidity of maximum 0.15% as lactic acid. An 8% salt addition is accepted. The end point is judged by using a refractometer. The product with required TSS is then pasteurized and filled into receptacles in the same way as explained under tomato puree.

11.10.4 Canned Tomato

The process of sealing tomatoes hermetically in containers and sterilizing them by heat for long storage is known as canning. The principle of canning is the destruction of spoilage microbes within the sealed container by thermal processing, i.e., by means of heat. Schematic representations of the unit operations are shown in Figure 11.7.

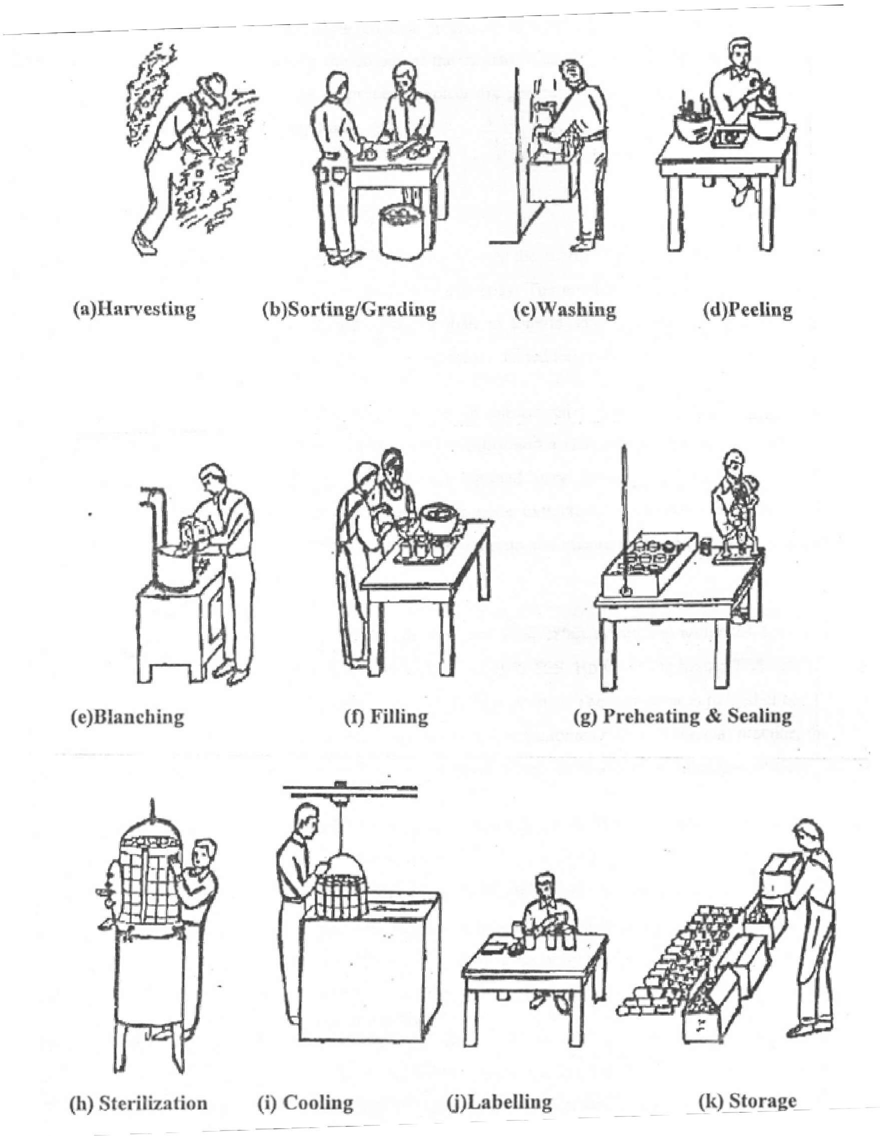

Figure 11.7: Schematic representation of fruit canning unit operations

Canning process: Canning involves the pre-treatments like selection of sound fruits and vegetables, grading, washing, peeling, cutting, blanching and cooling .The blanched tomato pieces are filled in plain cans and tomato juice is used as covering liquid. The filled cans are now subjected to exhausting for the removal of air and are then sealed immediately. The sealed cans are then thermally processed at high temperature (100°C) for about 25-30 minutes. After thermal processing, the cans are cooled rapidly to about 39°C to stop the cooking process and stored after labelling.

11.10.5 Tomato Sauce

Tomato sauce is the concentrated product prepared from the liquid extract from mature, sound, whole tomatoes to which is added salt, spices, sugar, vinegar, with or with out onion, garlic, or other vegetable flavouring ingredients. The final concentrated product contains not less than 12% tomato solids and 25% TSS. FPO specifications are given under quality standards.

Sauces can be obtained from fresh tomatoes or from concentrated products (tomato paste or concentrated tomato juice), those from fresh tomatoes being of superior quality. Technological processing covers the following steps: concentrated juice processing, addition of flavour/taste ingredients (salt, sugar, vinegar, spices, etc.), boiling, fine sieving, filling of receptacles, closing and pasteurization (45 min at 85°C).

Special care: About one third of the sugar required is added at the time of commencement of boiling to intensify and fix the red tomato colour. If the whole quantity of sugar is added initially, the cooking time will be longer and the quality of pulp will be adversely affected. Generally the sugar content in sauces/ ketchups varies from 10- 26 %. On the other hand, salt bleaches the colour of the tomato product. It is therefore desirable to add towards the end of cooking process. Spices are generally added in powdered form to the product by spice bag method.

11.10.6 Tomato Ketchup

Tomato ketchup is a popular condiment all over the world. Tomato ketchup is similar to tomato sauce except that it is thick in consistency. The amount of spices added in case of tomato ketchup is considerably higher than in tomato sauce. Thick sauces made from fruits and vegetables other than tomatoes are not called ketchups.

Preparation: Clean, wholesome tomatoes of intense red colour and of meaty, not watery texture are used for sauce making. High acidity and a rich tomato flavour are additional desirable qualities. Sound tomatoes are washed very thoroughly, cored, sliced, heat crushed and pulped (through a pulper or juice extractor) to remove seeds and skins. Tomato pulp or paste is then cooked with the requisite quantities of spices, onions, garlic, sugar, salt and vinegar.

The whole mass is concentrated to the required TSS (28%). A ketchup with a 28-30% TSS has a better flavour than those with more than 30% TSS. However the higher TSS ketchup generally keep for a long time, once the bottle is opened. The end point is judged either by means of a specific gravity hydrometer or by a refractometer. In commercial practice, the juice is concentrated to one third of its original volume as determined with a gauge stick.

Bottling: The mass is finally passed through the finisher, fitted with a very fine sieve, to remove any tomato fibre, and other impurities. The sieved ketchup is filled into clean, dry bottles. The ketchup should be filled hot (88^{o}C) to prevent browning and loss of vitamins during subsequent storage. Bottles are cleaned, labelled and packaged for marketing. Preservation is assured either by use of preservatives or by pasteurization.

11.10.7 Dried Tomato/Tomato Powder

Dried tomato is used for the production of flakes and tomato powder. For the preparation of dried product, tomatoes should be ripe, of good red colour and should be firm. Tomato pigments are stable because they are rich in carotene; therefore, pre-processing, such as blanching and sulphiting, is not necessary. Alternatively the slices may be dipped for 3 min in a solution containing 0.7% $K_2S_2O_5$ (KMS) plus 10% salt.

Washing and sorting are followed by cutting in halves lengthwise to eliminate the liquid and the seeds. Empty the tomatoes and then cut them lengthwise into slices of 6 to 8 mm thickness and place them in dryers. The tomatoes are dry when the raw material / dry product ratio is about 25:1. On an average, 40 g of dried products are obtained from I Kg of fresh tomatoes. The yield depends on the dry tomato residue and the degree of drying.

The dried slices may be reduced to flakes by rubbing through a sieve of about 10 mm mesh. This gives a better-looking product, which is easy to handle. The product may also be ground into powder but this will tend to cake and the colour is less appealing than the flakes. The product is then cooled (half an hour at room temperature), bagged and labelled for storage. The product must be kept in a dark place to reduce infestation by photophilic insects.

11.10.8 Tomato Soup

Soup is becoming very popular in India. Stored soup is warmed at the time of serving. The main constituents of the soup are tomato juice, butter or cream, spices, flour or starch (for thickening), onion, etc.

Preparation: In its preparation the first step is the preparation of tomato pulp just as in the case of tomato juice. Neutralize about $1/6^{th}$ of the acidity of the juice by adding a thin paste of sodium bicarbonate in water. The juice is then concentrated in a boiling pan. While it is being concentrated, add the spices in a cloth bag as in the case of tomato ketchup. In the meantime, mix the flour/ starch and butter/cream with one portion of juice (usually 10 to 15% of the total juice) to form a smooth paste. When the juice in the pan has been sufficiently concentrated, add this paste to it. Continue boiling to the desired consistency. Stirring is done continuously to prevent clotting of the starch. At the end, add sugar and salt and boil the mixture for about two minutes to dissolve them.

Bottling: The tomato soup is filled into cans and closed them properly for sterilization. Sterilization is carried out at 115^0C for 40- 45 minutes. The sterilized cans are cooled and stored in ambient temperature in a cool and dry place.

11.10.9 Chilly Sauce

It is highly spiced product made from ripe, peeled and crushed tomatoes and salt, sugar, spices, vinegar, with or without onion and garlic. The method of preparation is similar to that for tomato sauce except that the total unstrained pulp is used and the seeds are not removed. Hot product is filled in bottles or cans and processed in water at 85-90^{o}C for 30 minutes.

11.10.10 Tomato Pickle

Tomato pickles can be produced by using a combination of preservatives like salt, oil, spices and vinegar. The detailed method of the pickling process and flow chart for the same is explained under the section 3.3.4.

11.10.11 Tomato Chutney

Tomato chutney is produced from tomato pulp, and other ingredients like sugar, salt, vinegar, spices, onion, ginger, garlic, etc. The preparation of tomato chutney is similar to that of the chutney produced from other fruits and vegetables. The method of preparation is explained under the section 3.7.1.

11.10.12 Tomato Cocktail

Tomato cocktail is gaining popularity in many of the high-class hotels and restaurants. It is prepared just before serving and some times is also served from stock. In the later case, the cocktail is preserved by pasteurization in bottles. Although the recipes vary, the main constituent is tomato juice to which common salt, vinegar, Worcestershire sauce (Sauce from tamarind), lemon juice, etc. are added in different proportions to suit the palate.

The preparation of tomato juice is done in the similar way as explained in earlier products. Fresh or canned juice can be used for the cocktail production. Boil the tomato juice with the spices loosely tied in a cloth bag for about 20 minutes in a covered vessel. Then add the limejuice, vinegar and common salt. Only crystal clear limejuice should be used, because any sediment in it will impart an undesirable flavour.

Bottling: When all the ingredients have been mixed and the cocktail is ready for bottling, heat the cocktail to 82°C to 88°C and fill it into bottles, which have been sterilized and kept hot for filling. Close the bottles and keep them immersed in boiling water (100°C) for 30 minutes and then cool them.

11.11 MICROBIOLOGY OF RAW & FINISHED PRODUCTS

When tomatoes of poor quality are used in the preparation of tomato products, excessive amount of moulds, yeast, bacteria and fragments of insects lower the quality of the product. There are some prescribed limits for the mould, yeast and bacteria count permitted in the tomato products. Of these, mould count is the most important as it is the sure and positive indication of the condition of the tomatoes used. The insect fragment count is also highly indicative of gross contamination of the fruit and unhygienic conditions during handling and preparation of the raw material and finished products.

A minimum of 10 minutes heating of the sauce with 0.5% acetic acid could ensure the destruction of spore formers and addition of 750 ppm of sodium benzoate to the sauce would prevent microbial spoilage during storage.

11.12 PROBLEMS IN TOMATO PROCESSING AND MEANS TO AVOID THEM

11.12.1 Tomato Juice

- "Separation" in layers is due to not enough homogenisation or low / insufficient viscosity. In the first case it is necessary to intensify homogenisation; and in second to increase the pre-heating temperature to 60° C in order to obtain protopectine hydrolysis and pectolytic enzymes inactivation.
- Moulding of the juice is brought about by significant infection of raw materials, inadequate washing and control or by use of contaminated packages. The preventive measures should be decided after cause analysis. Good pasteurization can destroy all moulds but the bad juice taste remains.
- Fermentation of juice is manifested by a significant development of gases. Prevention methods are the same as for moulding.
- Tomato juice turns sour, without the formation of gases; this defect is initiated by thermophyl and thermo-resistant bacteria; the juice acquires a vinegary taste. Prevention: maintenance of flash pasteurization temperature at 130-135°C.
- Excessive vitamin C losses are due to a simultaneous action of heating and oxygen from air. It can be prevented by blocking air going into crusher and extractor, close receptacles in vacuum and assure an intensive de-aeration (vacuum degree 700 mm Hg) at a temperature of at least 35-40°C.
- Weak colour of tomato juice can be avoided by the utilisation of mature tomatoes and with a pulp of as red a colour as possible.

11.12.2 Tomato Paste and Puree

- Presence of sand is caused by inadequate washing or by a significant contamination of raw material; this can be prevented by a more intensive pre-washing and washing of tomatoes.
- There may be mould especially at the surface of tomato paste packed in drums. This can be prevented by accurate pre-washing and washing, following pasteurization instructions, packing in clean drums or receptacles, and closing receptacles immediately after filling.
- Fermentation is manifested by a weak alcohol smell or by a weak vinegar taste; when the fermentation is more advanced there is gas production in the product mass. Prevention: as for moulding prevention.

11.12.3 Tomato Sauces

Surface of the product turns black at the contact zone with air; this is due to the action of iron on the tannins from spices, tomato seeds, etc. Prevention is by avoiding iron equipments, avoiding crushing of tomato seeds and by sealing the receptacles under vacuum.

11.13 QUALITY STANDARDS

The importance of quality and its considerations has been discussed in detailed in Unit 1. Now we will see the FPO specifications for the products discussed in the present unit. FPO specifications for tomato products, pickles, chutneys and sauces are as follows:

Sl. No.	Product	Minimum TSS (%)	Mould count
1. 2.	Tomato juice Tomato soup	5.00 7.00	Not in excess of 30% of the field examined.
3. 4.	Tomato puree Tomato paste	9.00 25.00	Not in excess of 60% of the field examined
5.	Tomato ketchup/ sauce	25 .00(minimum acidity as acetic acid 1%)	Not in excess of 40% of the field examined
6.	Sauces other than tomato and soybean	15 .00(minimum acidity as acetic acid 1.2%)	Not in excess of 40% of the field examined

Permissible limits of preservatives in fruit beverages

Sl. No.	Food product	Preservative	Parts per million (ppm)
1.	Pickles and chutneys made from fruits and vegetables	Benzoic acid or Sulfur dioxide	250 100
2.	Tomato and other sauces	Benzoic acid	750
3.	Dehydrated vegetables	Sulfur dioxide	2000
4.	Tomato puree and paste	Benzoic acid	250

Some important considerations:

- In case of oil pickles the name of the fruit or vegetable used shall be declared on the label.
- When more than one vegetable is used in vinegar pickle the product shall be labeled as 'mixed pickles'.
- In case of sauces other than tomato and soybean, the names of fruits, vegetables or dried fruits used shall be declared on the label.
- In case of fruit chutney, the names of fruits may not be declared on the label, However, in case of mango chutney or other chutneys the content shall be declared on the label.

- Permissible limit of Copper (a toxic element) in tomato ketchup is 50 ppm, where as the same can be up to 100 ppm in tomato puree, paste, juice powder and cocktails.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the various unit operations in tomato juice preparation?

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2. List out the problems in tomato juice processing.

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3. How can we prevent microbial spoilage in tomato product?

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4. What are the three major steps in tomato puree and paste preparation?

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11.14 LET US SUM UP

Chutney, sauce and pickle are various processed products from fruits and vegetables prepared by using preservatives like salt, vinegar, oil, spies etc. In making such products, the major objective is to provide consumer with more variety among the processed foods and to provide convenience to have fast food. Apart from extending the shelf life of fruits and vegetables, these products enhance sensory properties and nutritive value of food

You must now be well versed with the methods of pickling and chutney and sauce preparation. We have also seen how to obtain diversified products from tomato fruit. Finally, the keeping quality, standards, packaging and storage aspects of the finished products are also explained in this section.

11.15 KEY WORDS

Brine	:	Solution of common salt.
Brining	:	Steeping of the vegetables in a salt solution of pre determined concentration for a certain length of time.
Vinegar	:	It is a liquid obtained by alcoholic and acetic fermentation of material containing sugar. It contains about 4% acetic acid.
Chutney	:	It is an unstrained, concentrated product, which contains a mixture of fruit or vegetable, spices, salt and/ or sugar, vinegar.
Sauce	:	It is a strained, concentrated product, which contains a mixture of fruit or vegetable, spices, salt and/ or sugar, vinegar. These are thinner and smoother in consistency than chutneys.
Tomato paste	:	It is a concentrated and strained tomato product and contains not less than 25% tomato solids.
Tomato puree	:	It is a concentrated and strained tomato product but thinner than the paste and containing not less than 9.0 % of salt free tomato solids.
Spice bag	:	Bruised spices tide loosely in muslin cloth
Ketchup	:	Thick sauces made from tomato

11.16 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. The preservation of fruit or vegetable in common salt or in vinegar is called pickling. Pickling is the result of fermentation by lactic acid forming bacteria, which are generally present in large numbers on the surface of fresh vegetables and fruits. These bacteria can grow in acid medium and in

the presence of 8-10% salt solution, whereas the growth of a majority of undesirable organisms is inhibited.

2. Vegetables preserved in vinegar need to reach a final concentration of 2-3% acetic acid in order to assure their preservation. To achieve this final concentration, a 6-9% acetic acid vinegar is used, as related to the specific ratios vinegar: vegetables. This higher concentration treatment also helps to expel the gases present in the intercellular spaces of vegetable tissue.

3. Different kinds of spoilage occur in pickles. They includes: bitterness, blackening, blemishes in case of onion pickles, cloudiness, dull and faded product, scum formation, shrivelling and the most common one is, softness and slipperiness.

Check Your Progress Exercise 2

1. Thin sauces mainly consist of vinegar extract of various flavouring materials like, spices and herbs. Their quality depends mostly on the piquancy of the material used. Where as thick sauce does not flow freely and is highly viscous. Thin sauces are less viscous in consistency. Thick sauces also contain more of sugar and less of acid.

2. Thick sauces made from tomato are known as ketchup. It is similar to sauce except that it is thick in consistency. The amount of spices added in case of ketchup is considerably higher than in sauce. Thick sauces made from fruits and vegetables other than tomatoes are not called ketchups.

3. Generally the sugar content in sauces/ ketchups varies from 10- 26%. If the whole quantity of sugar is added initially, the cooking time will be longer and the quality of pulp will be adversely affected. About one third of the sugar required is added at the time of commencement of boiling to intensify and fix the red tomato colour.

Check Your Progress Exercise 3

1. The various unit operations in tomato juice production include: Pre-washing, washing, sorting, crushing, pulping, extraction of the juice, de-aeration, homogenization, filling and bottling. The filled juice is subjected to flash pasteurization and intensively cooled to ambient temperature for storage.

2. The various problems in the production of tomato juice are as follows: i) Separation in layers due to improper homogenization, ii) Moulding of the juice, iii) Fermentation of juice, iv) Souring of tomato juice, v) Excessive vitamin C losses, and vi) Weak colour of tomato juice.

3. A minimum of 10 minutes heating of the sauce with 0.5% acetic acid could ensure the destruction of spore formers and addition of 750 ppm of sodium benzoate to the sauce would prevent microbial spoilage during storage.

4. The major manufacturing steps of tomato puree and paste fall into three, which includes: i) obtaining tomato juice from the raw materials, ii) juice concentration, and iii) tomato puree preservation by pasteurization.

10.17 SOME USEFUL BOOKS

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UNIT 12 DEHYDRATED PRODUCTS FROM FRUITS AND VEGETABLES

Structure

12.0 OBJECTIVES

The various points to be understood from this section are as follows:

- purpose of drying/ dehydration of drying of fruits and vegetables;
- procedure for dehydration of fruits and vegetables;
- methods and principles of different dehydration techniques; and
- packaging, storage and quality aspects of the dried products.

12.1 INTRODUCTION

Drying is the oldest known method of preserving food. Drying or dehydration is the removal of the majority of water contained in the fruit or vegetable. Although preservation is the primary reason for dehydration, it also lowers the cost of packaging, storing and transportation by reducing both the weight and volume of the final product. In addition, dried foods add variety to our diets. In the process of drying sufficient moisture is removed to protect the product from spoilage. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh material are retained after drying

In this unit, we will examine the various steps in the preparation of dehydrated fruits and vegetables. The importance of water activity and the effect of drying on product quality are also discussed in this section. We'll see the working principles of various methods of drying and the comparative merits and demerits of these techniques. You can also learn about the packaging, storage and the special care to be adopted during drying process.

12.2 DEFINITION

Drying or dehydration means the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, humidity and air flow. In this process a single layer of fruits or vegetables, as a whole or as pieces/slices are spread on trays which are placed inside the dehydrator. The initial temperature of the dehydrator is usually high which is gradually reduced.

12.3 USE OF DRIED FRUITS AND VEGETABLES

Of all food preservation methods, drying has received the most widespread and enthusiastic publicity in recent years. The use of dehydrated product has increased due to its advantages over other preservation techniques. The advantages are:

- The weight of a product is reduced to $1/4^{th}$ to $1/9^{th}$ of its original or fresh weight and thus the cost of transport is reduced.
- Due to reduction in bulk of the product, it requires less storage space.
- No preservative is added for its preservation.
- Nutrient concentration is very high per unit weight of dried product.
- Cost of processing is very low, as there is less labour and no sugar requirement.

Dried Fruits tend to be chewy and make delicious snacks. Pieces of dried fruits are good in cookies, muffins, cakes and breads. They can also be reconstituted and used in sauces, pies or added to gelatin salads, cooked cereals and ice cream. In addition to dried fruits, fruit leathers may also be used as snack foods.

Dried Vegetables can be used as chips or reconstituted for a cooked side dish. These are also used in soups, stews, casseroles and stuffings or made into powders. Campers and hikers value dried foods for their light weight, keeping qualities and ease of preparation.

12.4 STATE OF WATER IN FOODS

We know that the micro-organisms can grow very well at high moisture contents (above 80%). They get this water from the food in which they grow. If the water is removed from the food, water will transfer out from the bacterial cell too. This will stop multiplication of bacterial cells. In dehydration, it is important to understand the behaviour of water so that it can be removed most effectively and still leave a high quality product. Partial drying will be less effective than total drying, though for some micro-organisms partial drying may be quite sufficient to arrest bacterial growth and multiplication. Bacteria and yeasts generally require more moisture than moulds. Moulds can grow even on semi-dry foods on which bacteria and yeasts are difficult to survive. Example: moulds growing on partially dried fruits.

Water activity (a_w)

Food technologists often use a measure of "water activity" to describe how water interacts in food products. Water activity determines the lower limit of available water for microbial growth. It is defined as the ratio of the vapour pressure on the aqueous solution to that of pure water at the same temperature. Quantitatively, water activity is a measure of unbound, free water in a system available to support biological and chemical reactions. Water activity, and not absolute water content, is what bacteria, enzymes and chemical reactants encounter and are affected by, at the micro-environmental level in food materials. At the usual temperatures permitting microbial growth, most bacteria require a water activity in the range of about 0.90 to 1.00. Some yeasts and moulds grow slowly at a water activity down to as low as about 0.65.

The a_w has a major role to play on microbial spoilage and chemical changes produced in the food. The water activity of solutions containing solutes such as sugar, salts etc. will be less than 1. For food products, the a_w is generally less than 1. a_w is related to the moisture content of food, the types and concentration of different solutes, and the structure of the food. Two foods with the same water content can have different a_w values depending upon the degree to which water is free or otherwise bound to food constituents.

Free water and Bound water

The state of water in food is denoted by two types viz.; "free water and bound water". The working definition for these terms is "free water is that which gives water activity of one. Bound water gives water activity less than one. In drying process free water is relatively easy to remove from the food products, while bound water takes more energy to release from the food. This is because the bound water is bonded to the cell solutes. Thus the energy required to remove a molecule of water from a food increases as the water activity decreases. This is important to those who design drying operations, since energy is required to provide sufficient driving force for drying.

As a food product dries out and the water molecules becomes less mobile, physical changes also occur in the food. As water is removed, the product becomes more viscous, until a solid state is achieved on complete removal of the water. Thus the state of water present in the food or water activity plays an important role in determining the product quality.

12.5 FACTORS INFLUENCING DEHYDRATION

The drying operation of fruits and vegetables is a complex one since it involves simultaneous exchange of moisture and heat. Drying time in conventional ovens or dehydrators vary considerably depending on the amount of food dried, its moisture content, and temperature and humidity. Some foods require several hours and others may take more than a day. Prolonging drying time (by using lower temperatures) or interrupting drying time may result in spoilage.

Various factors that effect the rate of drying of horticulture produce include the following:

1. Composition of raw material.
2. Size, shape and arrangement of stacking of the produce.
3. Temperature, relative humidity and velocity of air.
4. Pressure.
5. Heat transfer to surface.

It is important to control the air temperature and circulation during the drying process. If the temperature is too low or the humidity too high (resulting in poor circulation of moist air) the food will dry more slowly than it should and microbial growth can occur. Watch temperature closely at the beginning and at the end of the drying period. If the temperature is too high in the initial phase, a hard shell may develop on the surface. This will prevent the removal of moisture from the interior portion and the moisture is trapped inside the food material. This is known as *case hardening*. Temperature, if too high at the end of the drying period may cause food to scorch. Temperature between 49^{o}C to 60^{o}C are recommended for drying fruits and vegetables. Temperature up to 65^{o}C may be used at the beginning, but should be lowered as food begins to dry. However during the last hour of the drying period, the temperature should not exceed 55^{o}C.

12.6 DRYING RATE CURVES

The drying rate curves show the rate of removal of moisture from the fruit or vegetable. There are three different ways to express this physical phenomenon. They are relation ships between drying rate, drying time and moisture content.

Drying time vs. drying rate: While drying, foods do not lose water at a constant rate and the rate of water removal under any set of fixed conditions drops-off as drying progresses (Figure 12.1). In practice, while we may remove 90% of the water in 2 hours, it may require more than 2 hours to remove most of the remaining 10% water. This becomes asymptotic so that zero moisture is never reached under practical operating conditions. This relation is explained in the drying curve "Drying time Vs Drying rate".

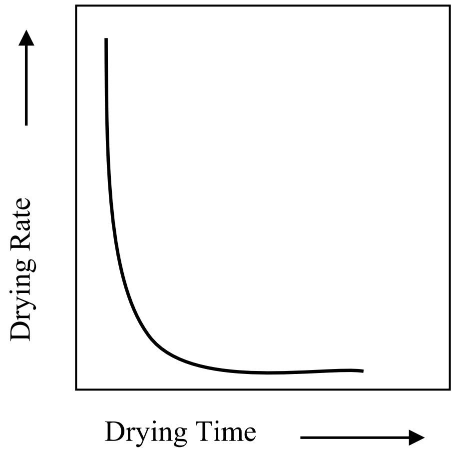
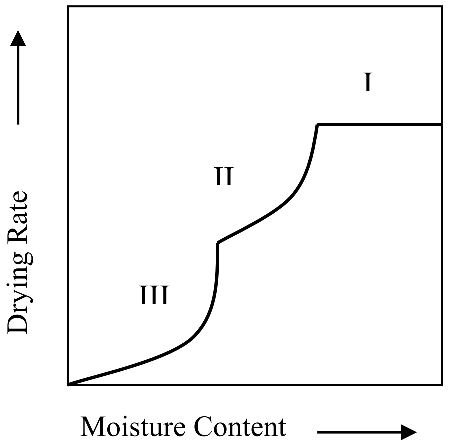


Figure 12.1: Drying time vs. drying rate

Moisture content vs. drying rate: At the beginning of drying, generally, water continues to evaporate from the food pieces at a rather constant rate. This is followed by an inflection in the drying curve, which leads to the falling rate period of drying. The precise shape of the normal drying curve varies with different food materials, different types of dryers and drying conditions. But the drying of most fruits and vegetables generally shows constant and falling rate periods. This relationship is as shown in the Figure 12.2. As the moisture content decreases, the drying rate changes from constant rate of drying to falling rate of drying. During the falling rate period, the rate of water movement from the interior of the food to the surface falls below the rate at which water evaporates to the surrounding air.



I- Constant rate of drying
II- First falling rate of drying
III- Second falling rate of drying

Figure 12.2: Moisture content vs. drying rate

Drying time vs. moisture content: The Figure 12.3 shows a drastic reduction of moisture in the initial phase of drying which reduces to a minimum as drying progresses. During drying process, the moisture content available in the commodity reduces and the removal of water to about 2% without product damage is exceedingly difficult.

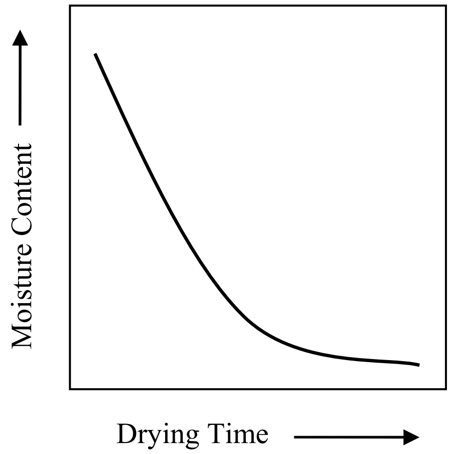


Figure 12.3: Drying time vs. moisture content

12.7 PROCEDURES FOR DRYING

Drying of fruit/ vegetable involves three stages; pre-drying treatments, drying of the commodity and post drying treatments. The flow diagram of drying process is shown in Figure 12.4.

Fruit/vegetables
↓
Washing
↓
Peeling
↓
Preparation
↓
Blanching
↓
Spreading on flat wooden trays
↓
Sulphuring (usually @1.8 to 3.6 kg per tonne of fruit)
↓
Drying/Dehydration
↓
Sweating
↓
Packing
↓
Storage

Figure 12.4: Flow chart of dehydration of fruit/vegetable

12.8 PRE-DRYING TREATMENTS

Pre-drying treatments include raw material preparation and colour preservation.

12.8.1 Raw Material Preparation

This includes selection of fruits, sorting, washing, peeling (for some fruits and vegetables), cutting into the appropriate form, and blanching (for some fruits and most vegetables). Fruits and vegetables are selected and sorted according to size, maturity and soundness. It is then washed to remove dust, dirt, insect matter, mould spores, plant parts and other material that might contaminate or affect the colour, aroma, or flavour of the fruit or vegetable. Peeling or removal of any undesirable parts is followed by washing. The raw product can be peeled by hand, with lye or alkali solution, with dry caustic and mild abrasion, with steam pressure, with high-pressure washers, or with flame peelers.

12.8.2 Blanching

Blanching is used to destroy enzymatic activity in vegetables and some fruits, prior to further processing. To achieve adequate enzyme inactivation, food is heated rapidly to a preset temperature, held for a preset time and then cooled rapidly to near ambient temperatures. The factors that influence blanching time are: the type of fruit or vegetable, the size of the pieces of food, blanching temperature and method of heating. The two most widespread commercial methods of blanching involve passing food through a bath of hot water or an atmosphere of saturated steam. It involved immersion in hot water (95^o to 100^o C) or exposure to steam to inactivate the enzymes present in fruits and vegetables. Both types of equipments are relatively simple and inexpensive.

12.8.3 Sulphuring

The final step in the pre-drying treatment is colour preservation, also known as sulphuring. The majority of fruits are treated with sulphur dioxide (SO_2) for its antioxidant and preservative effects. The presence of SO_2 is very effective in retarding the browning of fruits. In addition, SO_2 treatment reduces the destruction of carotene and ascorbic acid, which are the important nutrients for fruits.

In addition to colour preservation, the presence of a small amount of sulphite in blanched, cut vegetables improve storage stability and makes it possible to increase the drying temperature during dehydration. This will decrease the drying time and increase the dryer capacity without exceeding the tolerance for heat damage.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What do you mean by water activity? And why it is important for drying process?

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2. What are the factors influencing dehydration?

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3. What is the purpose of blanching?

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12.9 DRYING METHODS – THEIR PRINCIPLES AND METHODOLOGIES

Dehydrated fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method used. The selection of the optimal method is determined by quality requirements, raw material characteristics, and economic factors. There are three types of drying processes:

- Sun and solar drying,
- Atmospheric dehydration including stationary or batch processes (kiln, Oven, and cabinet/tray dryers) and continuous processes (tunnel,

continuous belt, fluidized-bed, foam mat, spray, drum and microwave-heated dryers), and

- Sub-atmospheric dehydration (vacuum belt, vacuum drum and freeze dryers).

12.9.1 Sun Drying

Sun drying depends on the weather, honors of sunshine, the temperature and the relative humidity outside. If you live in a hot, dry climate, sun drying may be successful. Its advantage is the low cost. The only investments are drying trays, netting to protect against insects and the food itself. Its main disadvantage is time. What would take 6 to 10 hours to dry using other methods may take 3 to 5 days in the sun. To avoid scorching, move the food into the shade to finish when it is about two-thirds dry.

12.9.2 Solar Drying

It is a modification of sun drying in which the sun's rays are collected inside a specially designed unit with adequate ventilation for removal of moist air. The temperature in the unit is usually 20 to 30 degrees higher than in open sunlight, which results in a shorter drying time. While solar drying has many advantages over sun drying, lack of control over the weather is the main problem with both methods. Solar drying utilizes black-painted trays, solar trays, collectors, and mirrors to increase solar energy and accelerate drying. A typical solar dryer is shown in Figure 12.5.

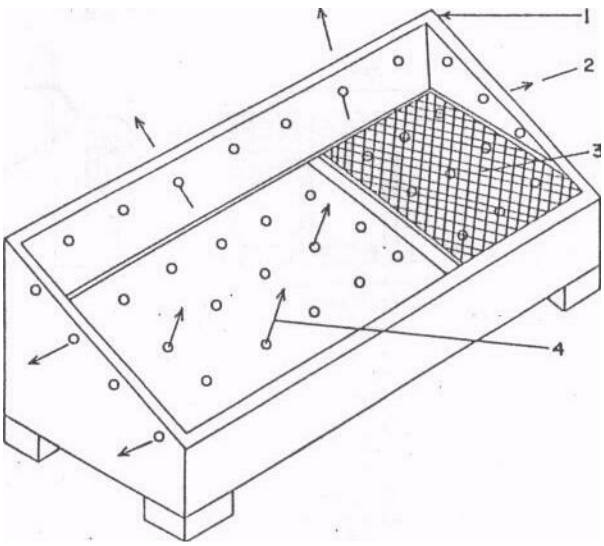

Figure 12.5: Solar cabinet driers: 1) Frame, 2) Exit air, 3) Drying tray, and 4) Air intake

12.9.3 Oven Drying

It is the most practical way to experiment with dehydration. It requires little initial investment, protects foods from insects and dust, and does not depend on the weather. Continual use of an oven for drying is not recommended because ovens are less energy efficient than dehydrators, and energy costs tend to be high. Also, it is difficult to maintain a low drying temperature in the oven, and foods are more susceptible to scorching at the end of the drying period. Oven-dried foods usually are darker, more brittle and of less flavour than foods dried by a dehydrator.

12.9.4 Osmotic Drying

Osmotic drying consists of removing a percentage of moisture from a fruit or vegetable by placing it in a concentrated solution of sugar, salt, or a combination of both. The principle of this drying is osmosis. It is the process of diffusion of water from dilute solution to concentrated solution through a semi permeable membrane. Here fruit cell wall itself will act as a semi permeable membrane. This is shown in Figure 12.6.

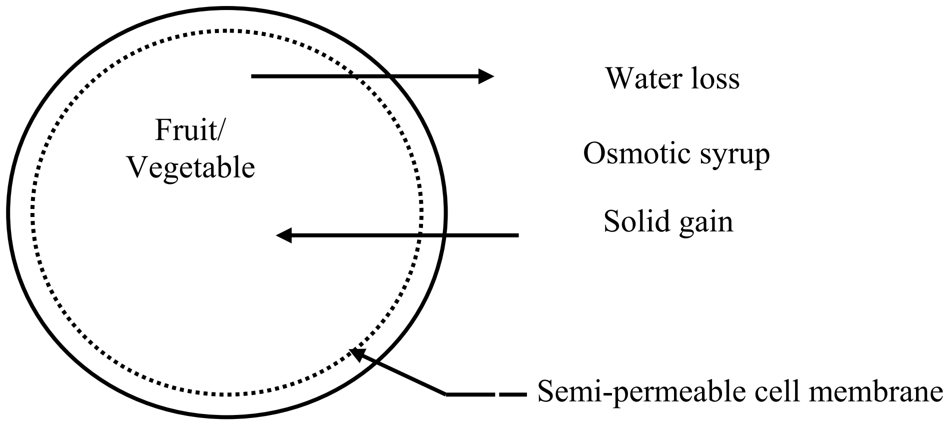

Figure 12.6: Principle of osmosis

The product is reduced to about 50% of its original weight by the osmotic dehydration process. This partial drying process is accompanied by any other drying processes viz. solar drying, vacuum drying, freeze drying, cabinet drying etc. The sugar syrup protects colour and flavour during the drying process. The product has a porous texture and retain a large percentage of the flavour volatiles of the fresh food. The various factors affecting the osmotic dehydration process are type of osmotic agent, concentration, temperature, agitation of syrup, size of the fruit pieces and fruit-to-syrup ratio.

12.9.5 Cabinet Dryers/Tray Dryers

In tray dryers, the food is spread out, generally as thin layer on trays in which the drying takes place. A typical tray dryer is shown in Figure 12.7. Heating may be by an air current sweeping across the trays, by conduction from heated trays or heated shelves on which the trays lie, or by radiation from heated surfaces. Most tray dryers are heated by air, which also removes the moist vapours. Hot air is circulated through the cabinet at 0.5–5.0 m/s per square metre tray area. A system of ducts and baffles is used to direct air over and/or through each tray to promote uniform air distribution. Tray dryers are used for small scale production (1-20 t/day) or for pilot scale work. They have low capital and maintenance costs but have relatively poor control and produce more variable product quality.

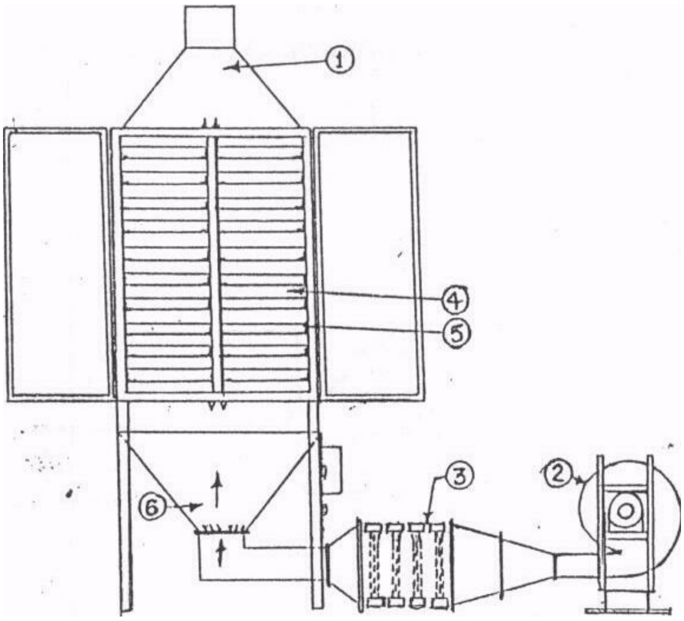

Figure 12.7: Schematic diagram of a typical tray drier: 1) Exit air, 2) Blower, 3) Heater, 4) Inter space between trays, 5) Trays, and 6) Plenum chamber

12.9.6 Tunnel Dryers

Tunnel dryers are the most flexible, efficient, and widely used dehydration system available commercially. These may be regarded as developments of the tray dryer, in which the trays on trolleys move through a tunnel where the heat is applied and the vapour removed. The product trucks are moved through the tunnel at a rate required to maintain the residence time needed for dehydration. The product may be moved in the same direction as the air flow to provide concurrent dehydration (Figure 12.8a), or the tunnel may be operated in a counter-current manner (Figure 12.8b) with product moving in the direction opposite to air flow. Sometimes the dryers are compartmented, and cross-flow may also be used. Typically a 20 m tunnel contains 12-15 trucks with a total capacity of 5000 kg of food. This ability to dry large quantity of food in a relatively short time (5-16 hours) made tunnel drying widely used.

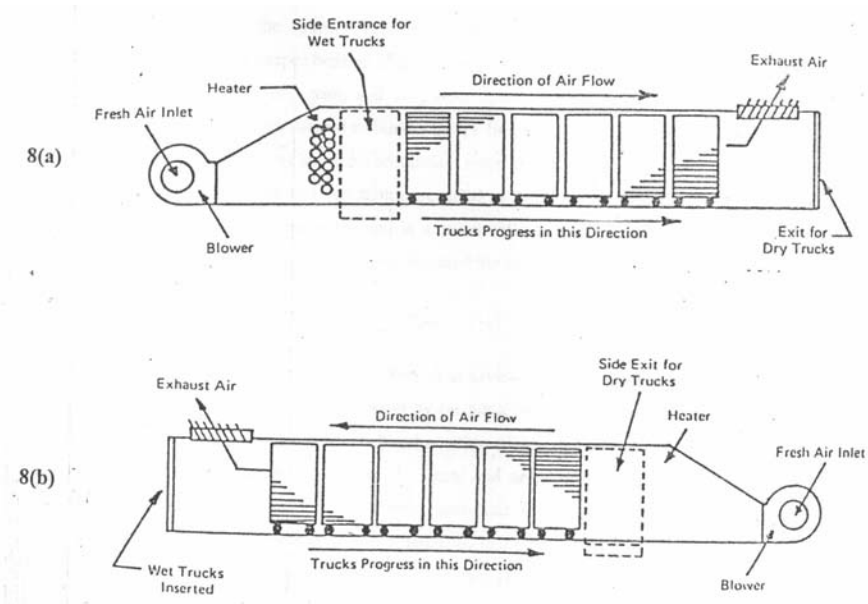

Figure 12.8: Schematic of tunnel driers: a) Concurrent flow drier, b) Counter-current flow drier

12.9.7 Conveyor Dryers or Belt Dryers

Continuous conveyor dryers are up to 20 m long and 3 m wide. Food is dried on a mesh belt in beds 5-15 cm deep. The air flow is initially directed upwards through the bed of food and then downwards in later stages to prevent dried food from blowing out of the bed. This is explained in the Figure 12.9. Two or three stage dryers mix and repile the partly dried shrunken food into deeper beds(to 15-25 cm and 250- 900 cm in three stage dryers). This improves uniformity of drying and save floor space. Foods are dried to 10-15% moisture content and then transferred to bin dryers for finishing. This equipment has good control over drying conditions and high production rates. It is used for large scale drying of foods (for example: fruits and vegetables are dried in 2-3.5 h at up to 5.5 t/h). It has independently controlled drying zones and is automatically loaded and unloaded, which reduces labour cost. As a result, it has largely replaced the tunnel dryer.

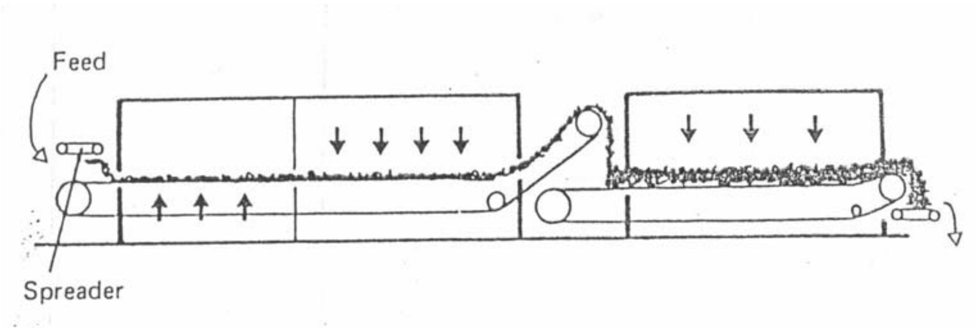

Figure 12.9: A typical two stage conveyor drier/belt drier

12.9.8 Foam Mat Drying

Foam mat drying is another application of conveyor dryers. In this method, liquid foods viz. fruit juices are formed into a stable foam by the addition of a stabilizer (e.g.: Xanthan gum, sorbitol, mannitol, alginic acid, etc.) and aeration with nitrogen or air. The foam is spread on a perforated belt to a depth of 2-3 mm and dried rapidly in two stages by concurrent and then counter current air flows. Foam mat drying is approximately three times faster than drying a similar thickness of liquid by belt drying. The thin porous mat of dried food is ground to a free flowing powder which has good rehydration properties. The rapid drying and low product temperatures result in a high quality product. However a large surface area is required for high production rates, and capital costs are therefore high.

12.9.9 Fluidized Bed Dryers

In a fluidized bed dryer, the food material is maintained suspended against gravity in an upward-flowing air stream. The air thus acts as both the drying and fluidizing medium, and the maximum surface area of food is made available for drying. There may also be a horizontal air flow helping to convey the food through the dryer. Heat is transferred from the air to the food material, mostly by convection. A schematic diagram of fluidized bed dryer is shown in Figure 12.10.

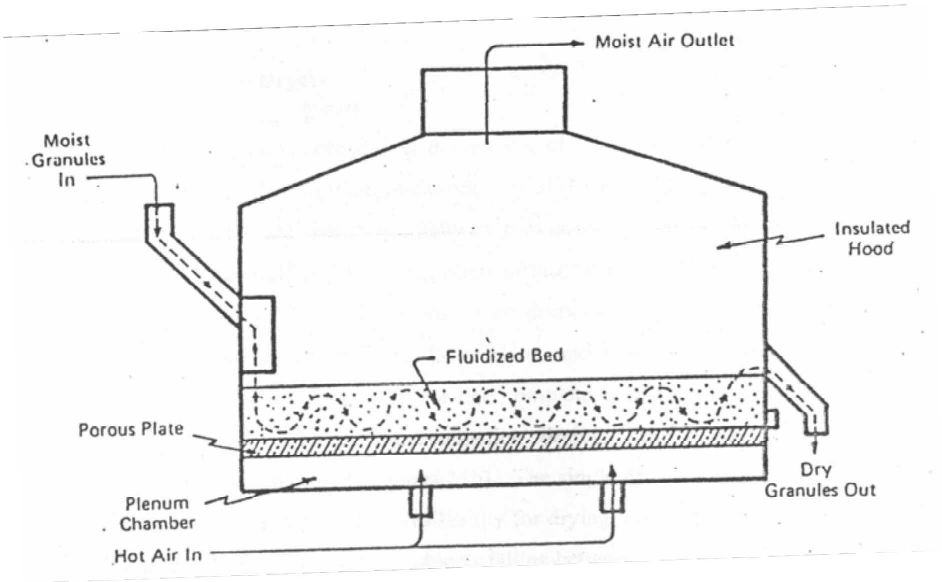

Figure 12.10: Schematic illustration of fluidized bed drier

Fluidized bed dryers are compact and have good control over drying conditions. They have relatively high thermal efficiencies and high drying rates. Fluidized bed dryers are limited to small particulate foods that are capable of being fluidized without excessive mechanical damage (e.g.: peas, diced or sliced vegetables, powders etc.)

12.9.10 Roller or Drum Dryers

In these dryers, the food in liquid or slurry form is spread over the surface of a heated drum. The drum rotates, with the food being applied to the drum at one part of the cycle. These drums are made of hollow steel drums and are heated internally by pressurized steam to 120-170^{o}C. A thin layer of food is spread uniformly over the outer surface by dipping, spraying, spreading or by auxiliary feed rollers. The food remains on the drum surface for the greater part of the rotation, during which time the drying takes place, and is then scraped off by using a 'doctor' blade. Usually the time taken for one complete revolution is 20s to 3 minutes. Drum drying may be regarded as conduction drying. Dryers may have a single drum (Figure 12.11a) or double drum (Figure 12.11b). The single drum is widely used as it has greater flexibility, a larger drum area availability for drying, easier access for maintenance and no risk of damage caused by metal objects falling between the drums.

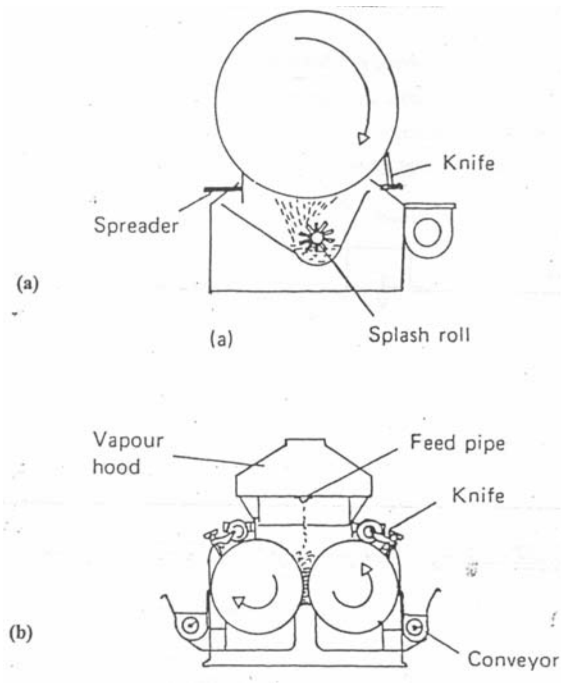

Figure 12.11: Drum driers: a) Single drum, b) Double drum

12.9.11 Spray Dryers

In a spray dryer, liquid or fine solid material in a slurry is sprayed or "atomized" in the form of a fine droplet (10–200 µm)dispersion into a current of heated air (150-300 ^{o}C). Complete and uniform atomization is necessary for successful drying. Air and solids may move in parallel or counter flow. A schematic of spray dryer is shown in Figure 12.12.

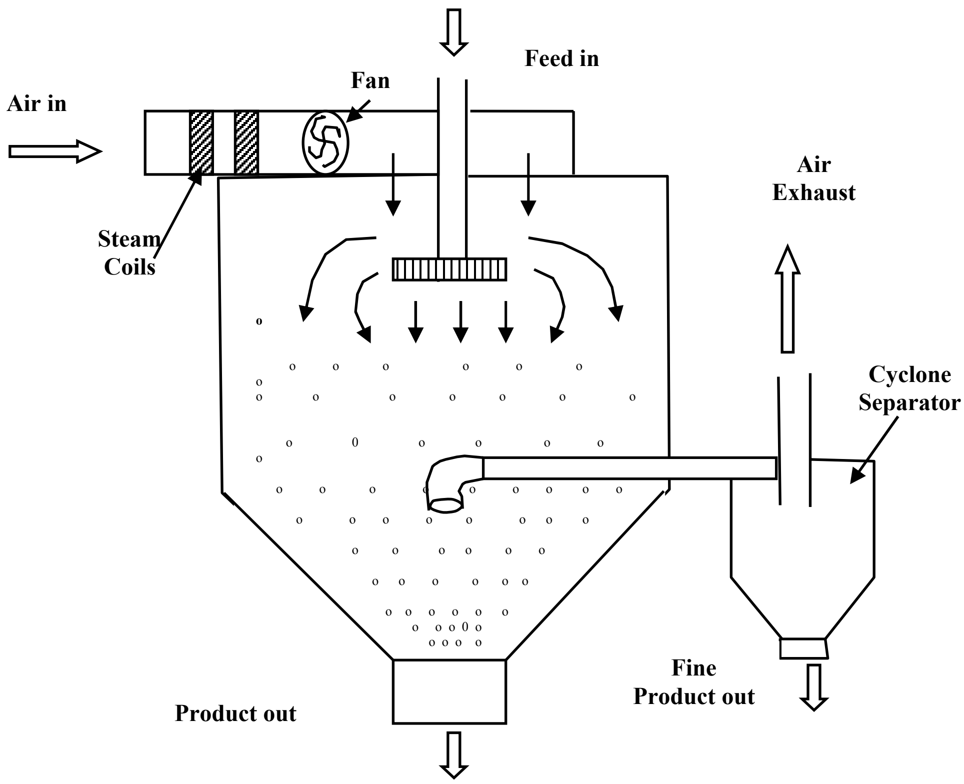

Figure 12.12: Typical schematic arrangement of a spray dryer

Drying occurs very rapidly, so that this process is very useful for materials that are damaged by exposure to heat for any appreciable length of time. The dryer body is large so that the particles can settle, as they dry, without touching the walls on which they might otherwise stick. Commercial dryers can be very large of the order of 10 m diameter and 20 m high. The dry powder is collected at the base of the dryer and removed by a screw conveyor or a pneumatic system with a cyclone separator.

The main advantages are rapid drying, large-scale continuous production, low labour costs and simple operation and maintenance. The major limitations are high capital costs and the requirement for a relatively high-free moisture content to ensure that the food can be pumped to the atomizer.

12.9.12 Microwave Drying

Microwaves are the portion of the electromagnetic spectrum between far infrared and the conventional radio frequency region. As the microwaves passes through the material such as fruits, the molecules within the food attempt to align themselves with the electric field direction. As they oscillate around their axis, heat is produced by the intermolecular friction within the product. This heat is responsible for the moisture removal from the fruits and vegetables. The depth of penetration is an important factor in microwave drying. A typical microwave dryer and its parts are shown in Figure 12.13.

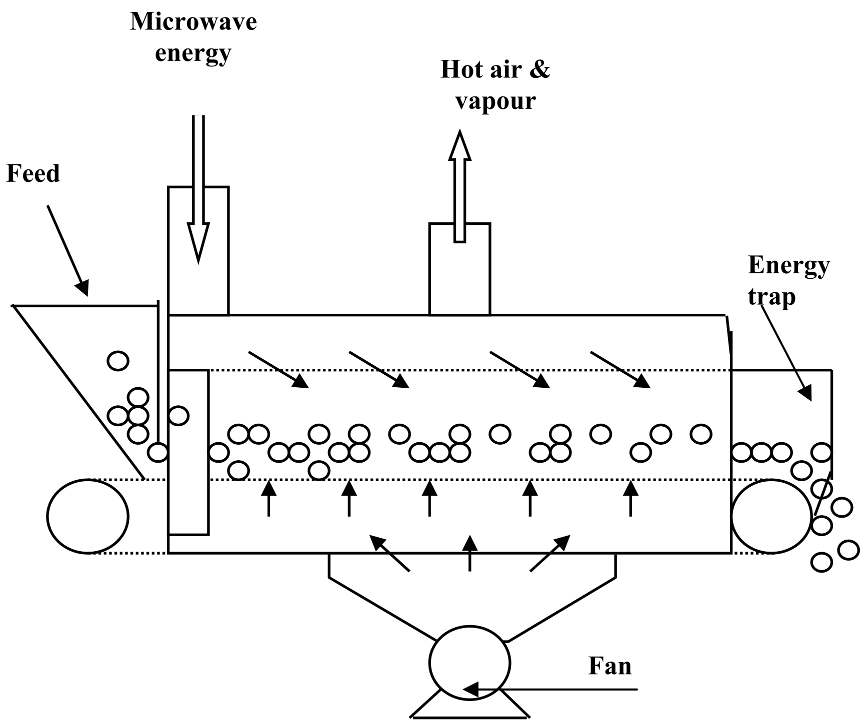

Figure 12.13: Schematic of a continuous microwave drying equipment

This method has been made use in drying of fruit juices, pulps, and fruit segments. Microwaves are endowed with some special characteristics such as (i) A penetrating quality which results in uniform heating of materials, ii) Selective absorption of radiation by liquid water, and iii) Capacity for easy control. These imparts some unique effects to the dehydrating materials such as improved quality and good texture.

12.9.13 Pneumatic Dryers

In a pneumatic dryer, the solid food particles are conveyed rapidly in an air stream, the velocity and turbulence of the stream maintaining the particles in suspension. Heated air accomplishes the drying and often some form of classifying device is included in the equipment. In the classifier, the dried material is separated, the dry material passes out as product and the moist remainder is recirculated for further drying. Pneumatic dryers have relatively low capital costs, high drying rates and thermal efficiencies, and close control over drying conditions. They are often used after spray drying to produce food which have a lower moisture content than normal. In some applications the simultaneous transportation and drying of the food may be useful method of material handling.

12.9.14 Rotary Dryers

The foodstuff is contained in a horizontal inclined cylinder through which it travels, being heated either by air flow through the cylinder, or by conduction of heat from the cylinder walls (Figure 12.14).

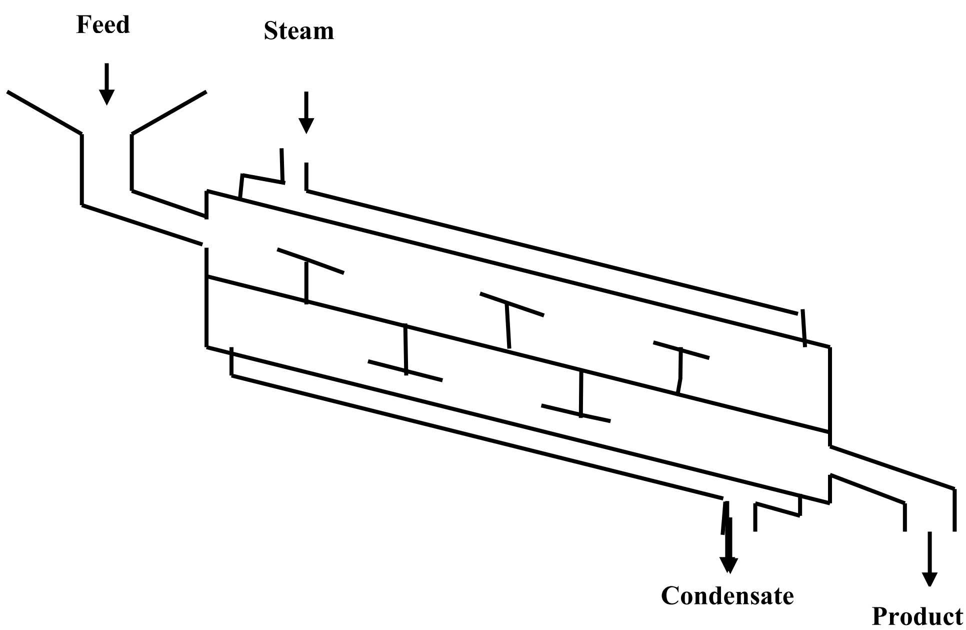

Figure 12.14: Rotary dryer

In some cases, the cylinder rotates and in others the cylinder is stationary and a paddle or screw rotates within the cylinder conveying the material through. The air flow may be parallel or counter current. The agitation of the food and the large area of food exposed to the air produce high drying rates and a uniformly dried product. This method is especially suitable for foods that tend to mat or stick together in belt or tray dryers. However, the damage caused by impact and abrasion in the dryer restrict this method to relatively few foods.

12.9.15 Vacuum Drying

Vacuum dryers are substantially the same as tray dryers, except that they operate under a vacuum, and heat transfer is largely by conduction or by radiation. It occurs at low air pressures and includes vacuum shelf, vacuum drum, and vacuum belt and freeze dryers. The main purpose of vacuum drying is to enable the removal of moisture at less than the boiling point under ambient conditions. Because of the high installation and operating costs of vacuum dryers, this process is used for drying raw material that may deteriorate as a result of oxidation or may be modified chemically as a result of exposure to air at elevated temperatures. In vacuum drying, the moisture in the food is evaporated from the liquid to the vapour stage.

12.9.16 Freeze Dryers

The material is held on shelves or belts in a chamber that is under high vacuum. In most cases, the food is frozen before being loaded into the dryer. Heat is transferred to the food by conduction or radiation and the vapour is removed by vacuum pump and then condensed. Schematic illustration of freeze drying system shown in Figure 12.15a. In one process, given the name accelerated freeze drying, heat transfer is by conduction; sheets of expanded metal are inserted between the foodstuffs and heated plates to improve heat transfer to the uneven surfaces, and moisture removal. The pieces of food are shaped so as to present the largest possible flat surface to the expanded metal and the plates to obtain good heat transfer. A refrigerated condenser may be used to condense the water vapour. A cross sectional view of freeze dryer is shown in Figure 12.15b.

(a)

b)

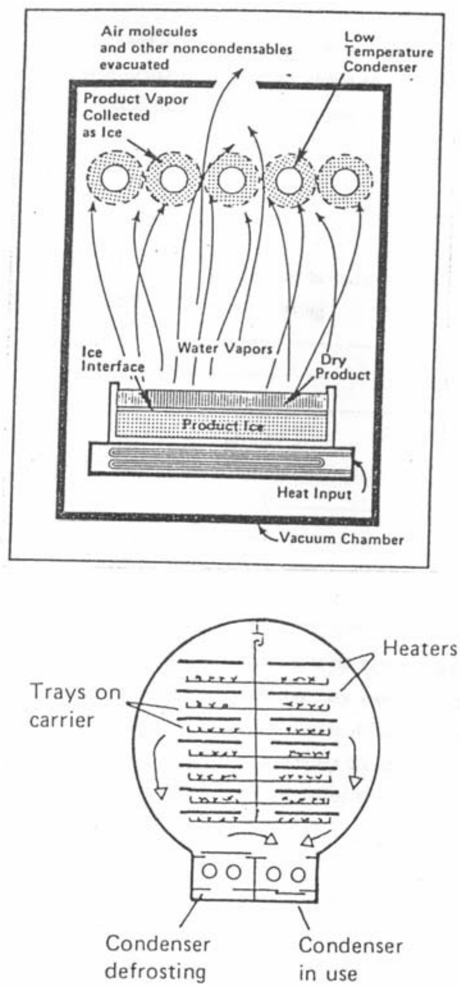

Figure 12.15: Freeze drying: a) Schematic illustration of freeze drying system; b) Cross-sectional view of a continuous freeze drier.

The advantages of freeze drying are high flavour retention, maximum retention of nutritional value, minimal damage to the product texture and structure, little change in product shape and colour, and a finished product with an open structure that allows a fast and complete rehydration. Disadvantages include high capital investment, high processing costs, and the need for special packing to avoid oxidation and moisture gain in the finished product.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are the advantages of using freeze drying?

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2. Explain the principle of microwave drying?

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12.10 POST-DEHYDRATION TREATMENTS

Treatments of the dehydrated product vary according to the type of fruit or vegetable and the intended use of the product. These treatments may include sweating, screening, inspection, and packaging. Sweating involves holding the dehydrated product in bins or boxes to equalize the moisture content. Screening removes dehydrated pieces of unwanted size, usually called 'fines'. The dried product is inspected to remove foreign materials, discoloured pieces, or other imperfections such as skin, carpal, or stem particles.

12.11 PACKAGING

It is commonly done for most of the dehydrated products and has a great deal of influence on the shelf life of the dried product. Packaging of dehydrated fruits and vegetables must protect the product against moisture, light, air, dust, micro-flora, foreign odour, insects and rodents. It should provide strength and stability to maintain original product size, shape and appearance throughout storage, handling, and marketing. The packaging materials used should be approved for contact with food. Cost is also an important factor in packaging.

Package types include cans, plastic bags, bins, and cartons, and depend on the end-use of the product. The details of packaging materials and its advantages are explained under the unit 1. It is better to pack dried foods in small amounts, since opening of a package can lead to moisture absorption and deterioration of its quality. Technical solutions for maintaining a low dehydrated products moisture are:

- Use packages that are water vapour proof. The most efficient packages are tin boxes or drums (mainly for long term storage periods); combined packages (boxes, bags, etc.); from complexes (carton with metallic sheets, plastic materials, etc.) mainly for small packages.
- Modern solutions are oriented not only to maintain the product moisture during storage but also to reduce the moisture by the use of desiccants (substances which absorb moisture) introduced in hermetically closed packages.
- Another factor that can deteriorate dried/dehydrated vegetables is atmospheric oxygen through the oxidative phenomena that it produces. In order to eliminate the action of this agent some packing methods under vacuum or in inert gases (carbon dioxide or nitrogen) are in use. Such packaging systems are used for packing dried carrots in order to avoid beta-carotene oxidation. To avoid the action of oxygen it is also possible to add ascorbic acid as antioxidant (for example in carrot powder).
- Sun or artificial light action on dehydrated vegetables generally causes discolouration which can be avoided by using opaque packaging materials.
- Store in a place with relative humidity below 78%.

12.12 STORAGE

The containers of dried foods are stored in a cool, dark, dry area such as a basement or cellar. Exposure to humidity, light or air decreases the shelf life of foods. Storage temperature has an important role because this reduces or inhibits the speed of all physico-chemical, biochemical and microbiological processes, and thus prolongs storage period. The lower the temperature, the better will be the shelf life of the product.

Foods stored at temperatures below 15°C will keep for approximately one year. At 27°C to 32°C the food begins to deteriorate within several months. In general, for every 10°C drop in temperature, the shelf life of fruits increases three to four times. The storage temperature should be below 25°C (and preferably 15°C); lower temperatures (0-10°C) help maintain taste, colour and water rehydration ratio and also, to some extent, vitamin C.

12.13 SUITABILITY AND ACCEPTABILITY OF DIFFERENT FRUITS AND VEGETABLES FOR DEHYDRATION

Fruits and vegetables selected for drying should be of the highest quality – fresh and ripe. Drying does not improve the quality. Immature produce will lack flavour and colour. Over mature produce may be fibrous or mushy. If the food is not perfect for eating, it is not suitable for drying. Different foods requiring similar drying times and temperatures can be dried together. Vegetables with strong odours or flavours (garlic, onion and pepper) should be dried separately. Don't dry strong-smelling vegetables outside in an electric dehydrator, because dehydrators are not screened and insects may invade the food.

Blanching is essential for all vegetables except onions, peppers, okra, herbs, and some new types of corn that get sweeter as they mature. Most fruits such as berries, cherries, seedless grapes, melons, prunes and plums does not require blanching before drying. Sulfuring has to be done for light-coloured fruits, especially apples, apricots, peaches, nectarines and pears, which tend to darken during drying and storage

Vegetables are sufficiently dried when they are leathery or brittle. Leathery vegetables will be pliable and, spring back if folded. Edges will be sharp. Sufficiently dry green peas shatter when hit with a hammer.

Fruits are adequately dried when moisture cannot be squeezed from them, and if tough and pliable when cut. Fruit leathers may be slightly sticky to touch, but should separate easily from the plastic wrap.

12.14 EFFECTS OF DRYING ON PRODUCT QUALITY

12.14.1 Nutritional Quality

The nutritive value of food is affected by the dehydration process. Large differences in the nutritive value of dried foods are due to wide variation in the preparation procedures, the drying temperature and time, and storage conditions. In fruits and vegetables, loss during preparation usually exceed those caused by the drying operation. Vitamins A and C are destroyed by heat and air. Sulfite treatment prevents the loss of some vitamins, but causes the destruction of thiamin. Blanching vegetables before drying results in some loss of Vitamin C, B-complex vitamins and some minerals because these are all water soluble. On the other hand, the loss of vitamins A, C and thiamin during dehydration and storage is reduced by blanching process.

Oil- soluble nutrients (vitamins A, D, E & K) are mostly contained within the dry matter of the food and they are not therefore concentrated during drying. However, water is a solvent for heavy metal catalysts that promote oxidation of unsaturated nutrients. As water is removed, the catalysts become more reactive, and the rate of oxidation accelerates. Fat soluble vitamins are lost by interaction with the peroxides produced by fat oxidation. Losses during storage are reduced by low oxygen concentration, low storage temperature and by exclusion of light.

There are more calories in dried foods on a weight-for-weight basis because of the concentration of nutrients. For example, 100 grams of fresh apricots have 51 calories, while 100 grams of dried apricots have 260 calories. Nutritive value, as well as flavour and appearance, is best protected by low temperature and low humidity during storage.

12.14.2 Texture

Changes in texture of solid foods are an important cause of quality deterioration. The nature and extent of pre-treatments, the type and extent of size reduction, peeling, affect the texture of rehydrated fruits and vegetables. In foods that are adequately blanched, loss of texture is caused by gelatinisation of starch, crystallization of cellulose, and localized variations in the moisture content during dehydration, which set up internal stresses. These stresses will rupture, compress and permanently distort the relatively rigid cells, to give the food a shrunken shriveled appearance. On rehydration, the product absorbs water more slowly and does not regain the firm texture associated with the fresh material.

The rate and temperature of drying have a substantial effect on the texture of foods. In general, rapid drying and high temperature cause greater changes than do moderate rates of drying and lower temperatures. In powders, the textural characteristics are related to bulk density and the ease with which they are rehydrated. These properties are determined by the composition of the food, the method of drying and the particle size of the product. Low fat foods (e.g.: fruit juices) are more easily transformed into free flowing powders than those rich in fat (e.g.: whole milk).

12.14.3 Flavour and Aroma

Heat not only vaporizes water during drying but also causes the loss of volatile components from the food. The extent of volatile loss depends on the temperature and solid concentration of the food and on the vapour pressure of the volatiles and their solubility in water vapour. Volatiles which have a high relative volatility and diffusivity are lost at an early stage in drying. Fewer volatiles components are lost at later stages. Control of drying conditions during each stage of drying minimizes losses.

A second important cause of aroma loss is oxidation of pigments, vitamins and lipids during storage. The open porous structure of dried food allows access of oxygen. The rate of deterioration is determined by the storage temperature and the water activity of the food. Flavour changes due to oxidative or hydrolytic enzymes are prevented in fruits by the use of sulphur dioxide, ascorbic acid or citric acid, by pasteurization of fruit juices and by blanching of vegetables.

Other methods which are used to retain flavours in dried foods include

- Recovery of volatiles and their addition to the product during drying.
- Mixing recovered volatiles with flavour fixing components, which are then granulated and added back to the dried product.
- Addition of enzymes, or activation of naturally occurring enzymes, to produce flavours from precursors in the food.

12.14.4 Colour

Drying changes the surface characteristics of food and hence alters the reflectivity and colour. Chemical changes to carotenoid and chlorophyll pigments are caused by heat and oxidation during drying. In general, longer drying times and higher drying temperatures produce greater pigment losses. Oxidation and residual enzyme activity cause browning during storage. This is prevented by improved blanching methods and treatments of fruits with ascorbic acid or sulfur dioxide.

12.14.5 Rehydration

Rehydration is the process of adding water to the dried products and is restored to a condition similar to that when it was fresh. This enables the food product to be cooked as if the person was using fresh fruits or vegetables.

Factors that affects rehydration process of the dehydrated or dried products are time, temperature, air displacement, and pH. Rehydration rate can be accelerated by ultrasonic treatment of the product to be rehydrated. Gamma radiation increases the rehydration rate of freeze dried products.

The level of reconstitution or rehydration is evaluated by using rehydration coefficient and rehydration ratio. *Rehydration ratio* is the ratio of the weight of the drained rehydrated sample to the weight of the dehydrated sample.

Rehydration coefficient is calculated by the following equation.

$$\text{Rehydration coefficient} = \frac{\text{DRW}\,(100 - \text{MC}_1)}{(\text{WD} - \text{MC}_2) \times 100}$$

where, DRW is the drained weight of the rehydrated sample.

MC_1 is the moisture content of the sample before drying.

WD is the weight of dried sample taken for rehydration.

MC_2 is the amount of the moisture present in the dried sample taken for rehydration.

12.15 SPECIAL CARE TO BE TAKEN DURING DRYING

There aren't many problems in food drying. However, here are some things to watch for.

Case Hardening – If the drying temperature is too high or the humidity too low, the food may harden on the surface. This makes it more difficult for the moisture inside to escape and for the food to dry properly.

Scorching – When black streaks or areas appear on the food, it has scorched. This is most common in sun drying and is why we recommend you to move the food into the shade when it is about two-thirds dry.

Souring – At the beginning of drying, if the temperature is too low or if the humidity is high,, the food may sour or ferment. It may even mould if conditions are too cold. Overloading the trays can also cause this problem.

Mould – Mouldy dried food should always be discarded. Check stored dried foods frequently to be sure that they remain dry. The presence of moulds demands either removal of more moisture in subsequent trials or storage of the dried food in the freezer.

Insects – All sun-dried foods should be pasteurized before storing to destroy insects or their eggs. Heat fruit and vegetables on trays in a 66°C oven for 30 minutes or put in freezer for 48 hours. Store food in insect-proof containers.

12.16 LET US SUM UP

Drying is an important and oldest preservation method in food processing. The main purpose of dehydration is to extend the shelf life of foods by a reduction in water activity. It also saves energy, money and space in shipping, packaging, storing and transportation. Due to these advantages the dried fruit or vegetable is known as high value low volume food.

In this section, we have detailed the procedure of dehydration which includes various pre-treatments, methods of dehydration and post treatments. The comparative advantages and limitations of the drying techniques are also discussed. You have also studied the different factors affecting drying and the suitability of commodities for drying. The importance of packaging, storage and rehydration of dried commodities are also briefed in this unit.

The future prospects of the drying industry seems to be quite encouraging since the dried/concentrated products are nutritionally good and easy to handle. There exists quite a good scope for the export of dehydrated fruits and vegetables as the demand for these products is on the rise in the world market.

12.17 KEY WORDS

Sulphuring : Pre-treating fruits with the fumes of burning sulfur.

Rehydration : Process of restoring moisture to a dried food.

Blanching : It is the process of inactivation of enzymatic activity in vegetables and in some fruits, prior to further processing.

Concurrent/Co-current flow dryer : Hot dry air and wet material enter at the same end and travel through the dryer in the same direction.

Counter flow dryer : Air flows in a direction opposite to the direction of travel of material through the dryer.

Sweating : Keeping the dehydrated product in bins or boxes to equalize the moisture content

Water activity : It is the water in a system available to support biological and chemical reactions

Bound water : This is the water bonded to the cell solutes or cell sap.

Fluidization : When the air velocity becomes higher than the critical velocity, the bed (drying product) progressively expands until it reaches a state of boiling or bubbling. This phenomenon is called fluidization.

Osmosis : It is process of diffusion of water from dilute solution to concentrated solution through a semi permeable membrane.

12.18 SELF TEST FOR THE COMPLETE UNIT/ ASSIGNMENT

1. Define drying?
2. Where should the dried foods be stored?
3. Does the calorie content of foods change during drying?
4. What are the common quality changes that may occur when foods are dried?

12.19 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Water activity (a_w) is defined as the ratio of the vapour pressure on the aqueous solution to that of pure water at the same temperature. Quantitatively, water activity is a measure of unbound, free water in a system available to support biological and chemical reactions. The a_w has a major role to play on microbial spoilage and chemical changes produced in the food. The energy required to remove a molecule of water from a food increases as the water activity decreases. This is important for drying operations, since energy is required to provide sufficient driving force for drying.
2. Various factors that effect the rate of drying of fruits and vegetables include: i) The Composition of raw material, ii) Size, shape and arrangement of stacking of the produce, iii) Temperature, relative humidity and velocity of air, iv) Pressure, and v) Heat transfer to the surface.
3. Blanching is the process to inactivate the enzymes present in the fruits and vegetables, prior to further processing. These enzymes cause deterioration of colour, vitamins, odour and flavour during storage.

Check your Progress Exercise 2

1. The advantages of freeze drying are high flavour retention, maximum retention of nutritional value, minimal damage to the product texture and structure, little change in product shape and colour, and a finished product with an open structure that allows a fast and complete rehydration.
2. As the microwaves passes through the material such as fruits, the molecules within the food attempt to align themselves with the electric field direction. As they oscillate around their axis, heat is produced by the intermolecular friction within the product. This heat is responsible for the moisture removal from the fruits and vegetables.

Answers to Assignments

1. Drying or dehydration means the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, humidity and air flow.
2. Store dried foods in a dry, cool, dark place. The higher the temperature, the shorter the storage time. Use clean, dry, insect-proof, moisture/vapour proof containers and package in small amounts to avoid constantly opening a container and exposing it to air.
3. The calorie content of foods does not change but is concentrated into a smaller mass as moisture is removed during drying. Therefore, on a per kg basis, dried foods contain considerably more calories than do the same foods fresh.
4. The various quality factors affected by the dehydration process includes nutritive value of food, fat oxidation, colour changes, texture changes, flavour and aroma changes.

12.20 SOME USEFUL BOOKS

1. David Arthey and Collin Dennis (1991). Vegetable Processing, Blackie Publication, New York.
2. Fellows, P. (1990). Food processing technology – Principles and practices. VCH Ellishorwood Publishers.
3. Fennemma, O.R. (1989). Principles of food science. Part 2–Physical principle of food preservation. Marcel Dekker, New York.

UNIT 13 SITE SELECTION AND LAYOUT

Structure

13.0 OBJECTIVES

After studying this unit, you should be able to:

- understand the importance of proper plant layout for efficient and optimum working environment;
- describe the general guidelines for layout of a fruits and vegetables processing plant; and
- explain various steps that can be taken for maintenance of clean working environment and workers' safety in a fruit and vegetable processing plant.

13.1 INTRODUCTION

In this unit we shall study about the various aspects of plant layout, which is nothing but the arrangement of different facilities and equipment in a plant. It begins with the importance of proper plant layout followed with the general principles of a plant layout. We will also discuss how a proper plant layout helps in saving of manpower and energy, and maintaining efficient and optimum working environment. And as you know, all of these parameters lead to the maximisation of profits.

This unit also covers different considerations for maintenance of clean working environment and safety of workers, which are very important for the survival of any industry. You will be able to comprehend that the working environment of the food processing plant and ultimate sustainability of the plant do not depend only on the plant operation management; rather a major part of it is also dependent on the plant layout, design and installation of different equipment and the safety measures. You will also know about the guidelines for placement of different equipment and other facilities in a fruit and vegetable processing plant.

13.2 SITE SELECTION

Suppose you want to establish a mango processing industry in a particular area, what type of questions would immediately come to your mind?

The first set of questions you would ask yourself is:

- Is sufficient quantity of good quality raw material available in the locality, or what will be the transportation cost for bringing raw material from another locality to the proposed processing site?
- Whether the auxiliary facilities such as electricity, water, labour, etc. are available in the locality?
- Is there any other associated problem for establishment of industry in the particular place?

The answers to all these questions should be favourable. These are some of the factors, which affect the site selection for any type of manufacturing industry. In fact many such factors have an effect on the site selection for any industry. If we don't give a realistic consideration to all these factors, we may face problems in running the industry in future.

In general, a proper site for a fruits and vegetables processing plant should have the following features.

- Adequate quantities of good quality raw materials should available in the nearby locality, because fruits and vegetables are highly perishable and deteriorate in very long distance transport.
- The fruits and vegetables processing plant requires a huge amount of water for processing, cleaning and other operations. Hence the area should have a good source of quality water supply, or a permanent water source should be created for the purpose.
- The environment should be as far as possible clean and free from debris and dust. The site should be at a considerable distance from other industrial factories, which may affect adversely the quality of processed product by spreading smoke, disagreeable odours, etc.
- There should not be any problem for availability of electrical power in the area. A standby generator will help in maintaining operation during power failures.
- There should exist proper transport facilities for the movement of raw materials and finished products.
- There should be easy availability of labour in the area.
- There should also be facilities for disposal of the waste, as this is becoming a matter of growing concern these days.
- There should be scope for future orderly expansion of the factory.

After we have selected an area or region for locating the plant, the next job is to select a specific site. The final site selection requires a careful scrutiny of experts. We should shortlist some probable sites and test their soil condition. If the soil doesn't have good bearing capacity, there will be more investment on foundation costs. Good natural drainage is another desirable feature. If the site is located near a stream or other body of water, we should check the flood history. In addition, consultation with officials of the neighbouring plants on the various nature of locations in the area and attitude of the local community is also helpful for deciding a suitable location for the plant.

13.3 IMPORTANCE OF PROPER PLANT LAYOUT

13.3.1 What is Plant Layout?

We may consider any food processing operation as a transformation process. In a fruit and vegetable processing plant, the raw materials (raw fruits and vegetables) are transformed into finished product (processed fruits and vegetables) by a series of operations, whose sequence and numbers are specified for the input. For example, the sequence of operations that are carried out in an onion dehydration plant, can be shown as in Figure 13.1.

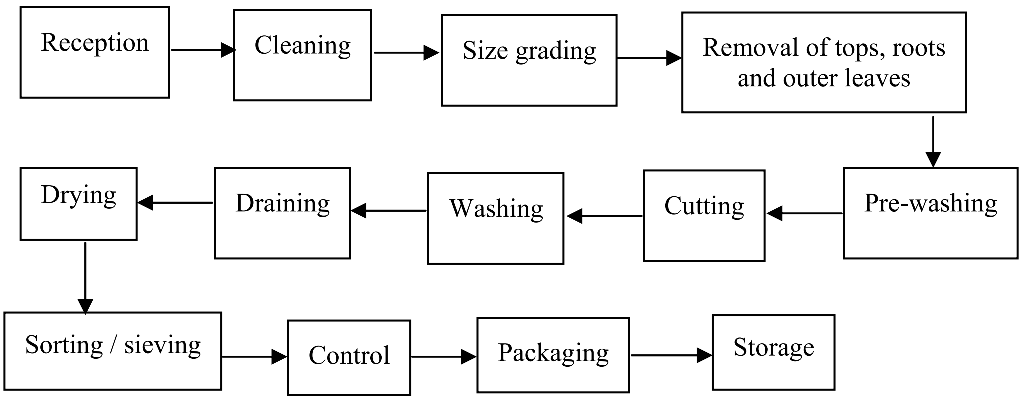

Figure 13.1: Processing of dehydrated onions

We can not change the sequence of these operations as per our desire. In this case, after receiving, the dust and dirt sticking to the surface of the onion bulbs must be cleaned first. Then the bulbs should be graded for size, then the tops and roots be removed, and so on. Therefore, for efficient utilisation of energy, labour (these are the other inputs than the raw materials), and of course money, the cleaning section should be kept adjacent to the receiving section followed by the grading section, and so on.

Now, suppose we place the size grader between the receiving yard and the cleaning section or the drying section between the packaging section and storage section, what do you think will happen? It will unnecessarily increase the materials handling cost and time, and reduce overall performance. In addition, it will also cause collision between the workers and wastage of manpower and energy. Hence, we should arrange the work areas, equipment and auxiliary facilities judiciously in the processing plant such that the operation will be economical and the employees will feel safe and satisfying.

Thus, the arrangement of the different facilities and equipment in a food processing plant plays an important role in the overall viability of the project. This physical arrangement of the industrial facilities is known as **plant layout**. The arrangement also includes the space needed for material movement, storage, indirect labour and all other supporting activities, or services, as well as for operating equipment and personnel.

13.3.2 Advantages of Good Plant Layout

In general, a good plant layout will permit simple and forward movement for the product and containers through the plant. Let us take a simple example.

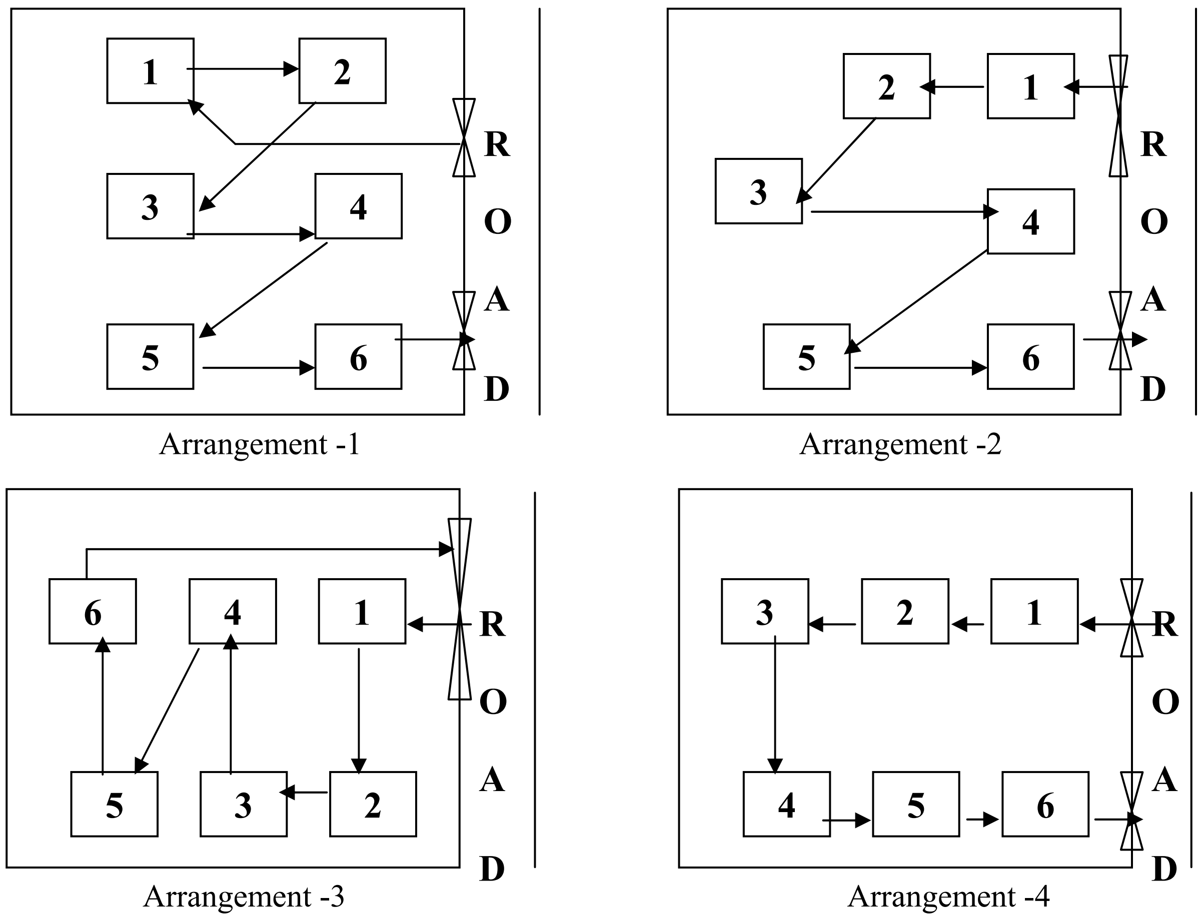

Figure 13.2: Understanding what plant layout means

In Figure 13.2, we have shown you some equipment in boxes, in which the numbers show the sequence of operations. Say, the first operation (may be cleaning) will be done by the Equipment-1, the second operation by Equipment 2 and so on. The Equipment 6 does the packing and then the product has to be taken out of the factory. I have shown you four possible arrangements for these equipment. Which pattern or arrangement do you think will be the best to reduce the cost of operation and improve performance?

Obviously Arrangement No. 4 will be the most ideal one. Remember, we are yet to learn the general guidelines for a good plant layout. However, you will definitely agree that if the machines are not properly arranged, as in the cases 1, 2 or 3, the total material movement inside the plant is unnecessarily increased. Besides, there is also crossing of the flow paths, which would interrupt a smooth operation.

The sequence of operations is one of the major criteria, but not the only criteria for designing plant layout, which we will discuss later in the unit. But as we are discussing about the advantages of a good plant layout, we wee that a proper plant layout helps us in reducing cost of operation, which is very important for survival of any industry.

A good plant layout, in general, has the following advantages.

- Saving in floor space;
- Better utilisation of machine and man power, and services;
- Reduced material handling, thus saving in labour and cost, less production delays;
- Reduced inventory in process, thus saving in investment and working capital;
- Increased output/ production per unit time, labour, money and energy; and
- Easier and better supervision.

In addition to the above, a properly designed layout helps to maintain proper sanitation and safety standards in a plant. It reduces confusion between different sections of workers, and improves moral of the workers. All these factors directly affect the output. Careful layout planning can identify and remedy bottlenecks and trouble spots before the plant is built, and thus prevents troubles later.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the major factors for selection of site for a fruits and vegetables processing plant?

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2. What are the main advantages of a good plant layout?

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13.4 GENERAL PLANT LAYOUT

In this section, we will discuss about the different requirements and general guidelines for a good plant layout. As we go on discussing the general guidelines, you will discover that a careful planning is very essential for the health of any industry, and in particular the industries processing fruits and vegetables.

13.4.1 Requirements/Factors in Planning Layouts

As we have already discussed, the basic objectives of a good plant layout are smooth operation and reduced cost in handling and processing. Further good layout must include arrangement of specified areas for processing, storage and handling in efficient coordination. This should also consider the following factors.

- ***Proper placement of equipment and conveying machines*** – All the equipment and conveying machines should be arranged in proper coordination depending on the flow sequence and characteristics of equipment. Depending on requirements, the layout can be single level, multi storied, or combined designs.

- ***Economic distribution of services*** – The layout, in addition to proper placement of important equipment, should also have provision for efficient and economic distribution of water, process steam, power, and gas, etc. The distribution lines for these utilities should not interrupt the normal working of the people.

- ***Suitable use of floor and elevation space*** – This will depend on the type of food processing plant and the special facilities and equipment used for the system.

- ***New site development or addition to a previously developed site*** – If we want to plan the plant on a site, which already has some installed equipment, office rooms and storage godowns, etc., then the layout should consider these amenities. Our objectives will be to see that minimum alterations or modifications are made to the existing facilities without affecting the overall objective of the layout.

- ***Future expansion*** – The layout should have sufficient provision for future expansion. Suppose at this stage we are interested in a 1 tph (tonne per hour) dehydration plant for ginger. But after some years, we want to increase the capacity to 4 tph or want to prepare dehydrated onion and garlic from the same plant. It requires installation of some more equipment. We will also need more space for godown and processing operations. In that case, we will be in trouble if the present arrangement doesn’t have sufficient provision for expansion. Another alternative is to install a completely new plant in another location. It will involve some unnecessary cost and further it will also be difficult to manage two plants at two different locations. To overcome such type of difficulties, the layout should have provision for future expansion.

- ***Waste disposal problems*** – The layout should have adequate provision for disposal of solid, liquid and gaseous wastes. Or else, the project may not be even passed by the pollution control authorities.

- ***Safety considerations*** – We should keep the equipment or areas having chances of hazards like fire or explosion away from normal working of the people. For example, we should isolate the boiler room.

- ***Other factors*** – The building code requirement, weather conditions like extreme high or low temperatures, maximum wind speed in the area, etc. are some other factors which need to be considered during planning the layout.

13.4.2 Types of Layouts

There are generally two types of product flow in food processing industry, namely, **line flow process** and **intermittent flow process.** In the line flow process, the product flows from one operation to the next in a prescribed sequence as in the preparation of homogenised and pasteurised milk in an automatic dairy plant. The individual work tasks are closely coupled. There may be side flows, which impinge on this line, but they are integrated to achieve a smooth flow. In an intermittent flow process the production is carried out in batches at intermittent intervals. In this case, we can organise the equipment and labour into different work centres by similar types of skill or equipment. The product can be sent to any of the work centres as per requirement. For example, in a mango processing plant, the mango slices can be sent to a dehydrator for preparing dried mango slices or sent to the canning section for getting canned mango slices, or may be filled with syrup and frozen to prepare frozen mango slices. Similarly mango pulp can be processed in different work centres to get frozen mango pulp, mango squash, mango nectar, mango bar, mango powder or mango cereal flakes. Or, say the particular squash manufacturing section can be used for different commodities like mango, pineapple, lime or watermelon at different times. This often results in a jumbled pattern of flow. The volume of product handling can be changed easily in this type of flow.

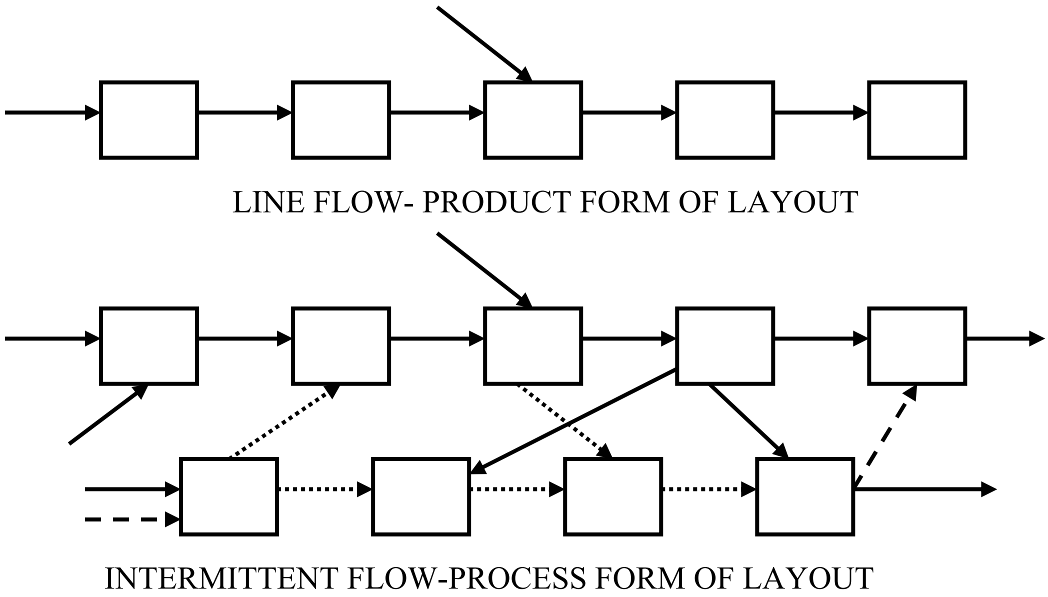

Figure 13.3: Product form and process form of layout

Based on the above classification of flow processes, the layouts also differ. The intermittent process is also known as a **process form of layout** as similar equipment and processing operations are grouped together. It is also known as 'layout by function'. The line flow is also called a **product form of layout** because various process equipment, and labour skills are put into sequence according to the way the product is made.

When a product lacks standardisation or the volume of product is low, the intermittent operation is economical and involves least risk. If an industry produces high volume of one or a few products, then layout by product or flow-line layout can be used. The equipment are placed in sequence, either on a straight line, or in shapes like U, L or convoluted or serpentine shape. As the raw material is processed, some products and by-products may move away from the principal direction of the flow.

Many modifications to above flow patterns are possible. A **hybrid layout** is one, where some portions may be layout by process and some portions by product. Generally the small food processing plants have process form of layout, whereas bigger industries have hybrid layouts.

Another type of classification of layout is single level, multi-storey or combined layout.

13.4.3 General Guidelines for Layout of a Fruit and Vegetable Processing Plant

After obtaining some idea on the factors affecting the layout planning and the different types of layout plans, in this section, we will give a closer look at different aspects of layout of a fruit and vegetable processing plant.

Layout of different sections / buildings

After a complete study of the requirements of the plant, the selection of the building or buildings must be considered. The building should be designed around the process, not a beautiful structure into which the process must fit.

Different products may each have their own processing room or area, or they may be housed in a single room with different allocated area. The primary rooms should be planned larger than necessary, for possible future expansions. We should keep in mind that the height is also equally important as the floor space requirement for layout planning.

The office room needs to be accessible to suppliers, customers and visitors. In large plants it can be kept at the main entrance as a separate building. The office accommodation should also contain a reception room and a demonstration room for study groups, etc. For small plants such offices are contained in the main building. The main laboratory can be conveniently put on an upper floor of the administrative building or next to the office room so that manager can easily control both administrative and technical services.

Reception and dispatch rooms should be situated on the ground floor having good access to main gate. The reception platform should be at a height to suit the vehicles concerned. In small plants loading and unloading, and conveying within the plant are done manually, In large plants, if mechanical conveyors or hydraulic conveyors are to be used, then the conveying section has to be planned simultaneously with the reception section.

Storage facilities for raw materials and intermediate and finished products may be located either in isolated areas or in adjoining areas. While considering for storage, the amount of handling involved for carrying the materials from reception to the storage section or from the storage to the processing section should be considered. However, sometimes storage of materials in adjoining areas to reduce materials handling may create problem for future expansion of the plant. Hazardous materials, if stored in large quantities, should be isolated.

Areas involving dust, dirt, oil and fumes, which may contaminate the products must be separated from processing or storage areas. The boiler room, fuel store, repair shop, compressor rooms are such types of areas.

The orientation of prevailing winds, the polluting potential of the air, topography of the site and access to roads must be considered when fixing the position of different rooms. Direct exposure of certain areas of the plant to the summer sun may be undesirable.

Layout of equipment

The information on exact space needed for installation of each equipment is very important for planning. The design and capacity of equipment will determine the floor space. Manufacturers normally give the dimensions of their equipment including floor space required. Besides, there should be adequate space for convenience in operation and maintenance, while still practising economy of floor space and good housekeeping in the plant. Allowances for working space should be five times the floor space occupied by the equipment. Floor area for dry store and office spaces should each be 25% of the plant floor area. The floor areas should also include space for possible additional equipment.

The equipment that need frequent servicing needs special care. There should be space for lowering the overhead equipment for maintenance. Besides, it is not wise to fit the equipment too closely in a building. A slightly larger building that appears unnecessary will cost little more than the one that is crowded, but this will help in maintenance of proper sanitation, safety and comfort of the operators.

We must consider the relative levels of several pieces of equipment and their accessories before placement. For gravity flow, the materials are first lifted to a higher level, and hence, a multi-storey layout is often necessary. The cost of mechanical transportation is greatly reduced in single storey plant.

In most of the cases, a group of operations are carried out simultaneously, for example, in a canning plant the can filling, exhausting, and can closing are such type of operations. So we can group the necessary equipment in proper sequence in a single room. It helps us in division of operating labour so that some specialised operators can be trained to attend all equipment of the group.

Suppose at any point of time we need to bypass a machine or a section, then the plant layout should be such that it allows that with minimum of alterations.

Layout of materials handling equipment

As we have discussed previously, considerations for materials handling should accompany the equipment and buildings layout. Suppose the materials are to be carried by crates on a chain conveyor from the receiving yard to storage, then the layout should have provision for that, in addition to working space for the labourers. Wherever possible, we should take advantage of the topography of the site location. The working surface of the conveyor must be at a height to facilitate the operations, which may be involved.

Lay out of service facilities

The important service facilities for any type of food processing plant are water, steam, power, electricity, gas and air. Proper placement of the distribution lines for the above services help in ease of operation, orderliness, and reduction in costs of maintenance. For example, we must not lay any pipe on the floor or up to a height of 7 ft level, where the operator is expected to move during the work. Chaotic arrangement of piping invites chaotic operation of the plant.

The service lines should be as short as possible to reduce capital investment and running costs. In small plants it is practicable to provide accommodation for steam production, refrigeration and electricity within the main building. In large plants, this is often not possible, and the service rooms are grouped in a separate building. The switch room may be as central as possible, to economise in wiring. In large plants more than one switch room may be necessary. The generator room should be adjacent to the switch room.

The boiler house must provide accommodation for the steam boilers and auxiliary equipment, such as feed water tank, feed water treatment plant etc. The type and capacity of the boilers greatly influence the space required. A working space of 1-2 m should be allowed between boilers and other equipment or wall of the building to give access for maintenance. The space in front of boiler must be much higher than this for cleaning of flue tubes and their replacement. The room or house for the boiler is usually separated from the main plant building in compliance with legal requirements.

The refrigeration machinery should be grouped in one room, but if separate compressor(s) are used for direct refrigeration, they must be placed close to the room, which they cool. Longer service lines need more cost of refrigerant required to charge the system, and thus higher will be the running costs.

Layout of waste disposal system

The disposal of wastes, which include liquors, fumes, dusts and gases, need special attention. The wastes should not affect the local community. If the wastes are not disposed properly, they will attract local dissatisfaction and prosecution by law, which will harm the unit in long run. The special equipment installed for ventilation, fume elimination, and drainage should not interfere with the flow of materials in process.

Other considerations

We should locate the windows / doors/ ventilators to allow maximum possible thermal circulation of air. Proper orientation of the buildings in respect to the solar position and prevailing wind direction is also important.

The local and national safety and fire code requirements are important factors while arranging the equipment and buildings in a plant. Different fire protection devices must be incorporated to protect costly plant investment and reduce insurance rates.

Existing or possible future rail roads and roads adjacent to the plant should be considered for placing the layout of building and auxiliary facilities. There should be proper access to all parts of the plant. Sufficient free space should be kept in the initial planning for future expansion.

13.4.4 Steps of Layout Planning

The steps involved in layout development are as follows:

First we have to decide the process and the type of layout design. The factors affecting process selection are capital, market conditions, labour, management, raw materials and viability of technology. As mentioned before, a complete understanding of the different unit operations involved in the process is essential. Layout has to be done for individual sections, and for individual equipment inside each section.

Then the preparation of the product flow charts is the next step in planning. The product flow chart shows 'how the product is processed', in addition to the transportation and storage activity. An example of a simple flow chart is shown in Figure 13.4 for manufacture of tomato sauce.

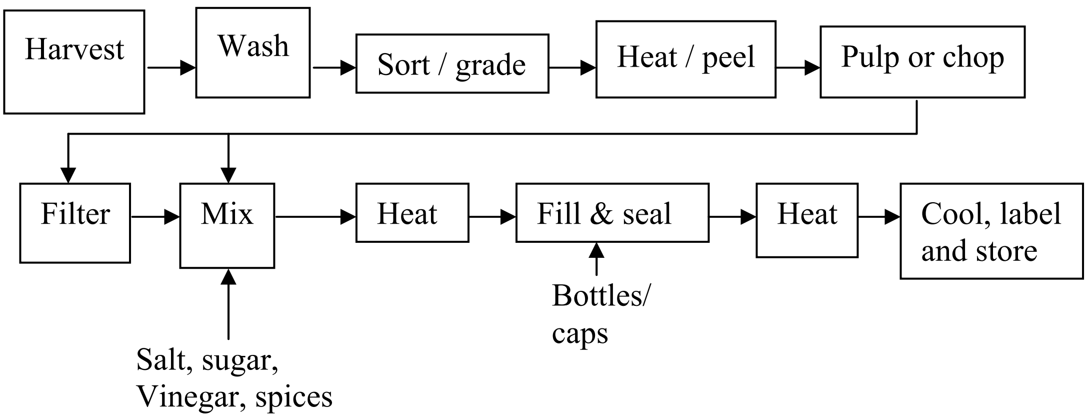

Figure 13.4: Product flow chart for tomato sauce

After preparing the product flow chart, we have to decide the principal equipment; the flow lines are then converted to machine lines. The designer must have a complete knowledge on the space requirements for individual pieces of equipment, for processing, storage of products and by-products, and for the working of people. At a later stage of process planning, the make or capacity of certain item may be changed when the particular details of the equipment become fully available, or we find better equipment during the planning process.

As the layout design develops it should be drawn on paper. After appropriate revisions, detailed drawings can be made to show the exact location of equipment and distances. Scale drawings are widely used in layout planning. We arrange the basic blocks or sections and arrange them in plot plans. Thus, the shape and extent of any area/section is described and the interrelationship between each area is shown. This is also known as 'Unit area concept' of planning.

Two dimensional scaled templates or small cutouts of unit areas and equipment within each area are placed on crosshatched scale paper. After repeated investigations and with different combinations/alterations, a basic plot plan is prepared with detailed two-dimensional diagrams, and is shown in a series of drawings.

Three dimensional scale models prepared from blocks of wood and cardboard give a better representation than the two-dimensional drawings. In bigger models, the piping and utilities can be shown. Now-a-days softwares are available for layout planning of process facilities using computers.

13.4.5 Example of Plant Layout

In Figure 13.5, we have shown you a typical example of fruit processing plant layout. Check how the raw materials receiving and storage and processed product storage are isolated from each other. See that the raw material enters

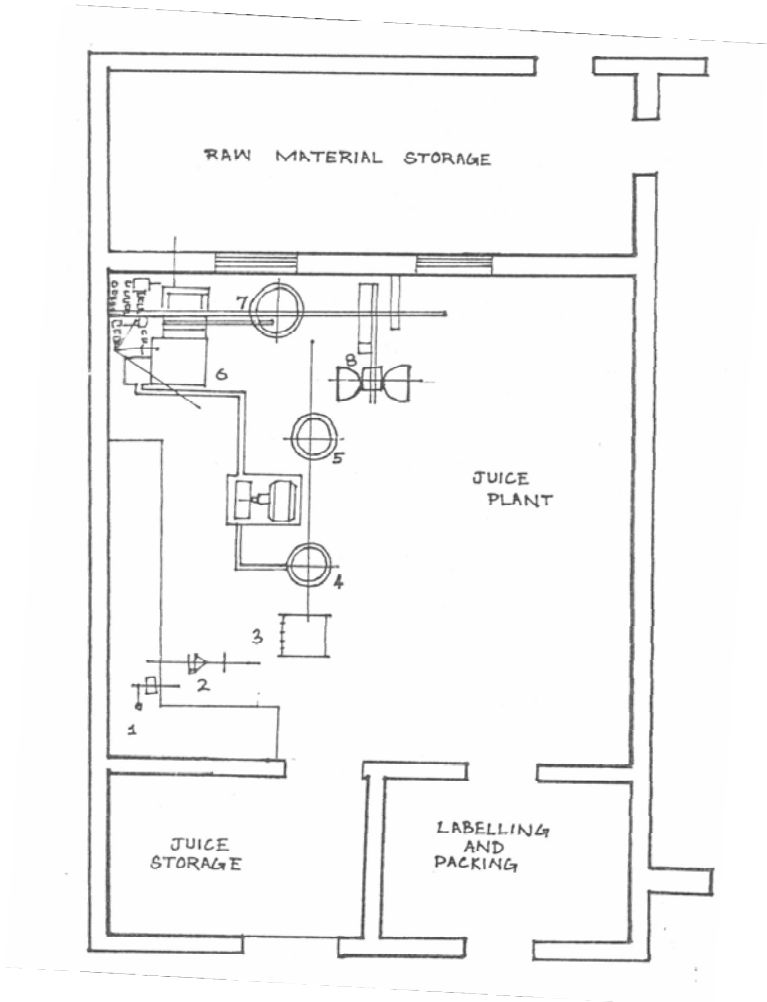

Figure 13.5: Layout plan of a fruit juice plant: 1) Capsular, 2) Corker, 3) Filler, 4) Syrup agitator, 5) Syrup maker, 6) Pulping M/C, 7) Pump, and 8) Pulp extractor

the processing room from one side and exits from the other. In the processing section, all the equipment are arranged in sequence so as to avoid criss-crossing of the flow lines. Besides, also observe that sufficient working space is kept in the processing room, which will avoid collision between workers and avoid accidents, and also help in maintenance of the equipment. Many arrangements or alternate layouts are possible for this kind of plant. But the basic features that we have studied in the previous section should be carefully incorporated in the system for optimum working conditions.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the basic objective of a good plant layout?

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2. Why considerations for future expansion is important during designing of a plant layout?

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3. What are the different types of plant layouts?

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4. What are the advantages of 3-dimensional scale models over two-dimensional representations?

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13.5 ANALYSIS OF MAN AND MATERIAL MOVEMENT

In a fruit and vegetable processing plant, in addition to the cost of raw material and its processing, the other major costs involved are the cost of labour, storage, transport and distribution. Hence we must try to minimise the material handling cost as well as employee travelling time, which also affect the viability of the project. Similarly, mechanical handling equipment consume a lot of power and by generously planning the layout, a considerable saving is possible with this aspect.

The total cost involved in a plant for transportation can be expressed as follows:

$$C = \sum_{i=1}^{N} \sum_{j=1}^{N} T_{ij} C_{ij} D_{ij}$$

where C = Total cost

T_{ij} = Trips between section i and section j

C_{ij} = Costs per unit distance per trip travelled from i to j

D_{ij} = Distance from i to j

N = Number of sections

Here C can be considered in rupees or time units to accommodate materials handling or travelling time criteria. The trips between any two sections will depend on the quantity of materials handled, and hence, once the plant capacity is decided, the number of trips between sections becomes apparently constant. The cost per trip is regulated by the labour rates or power utilised in the conveying machines, and for the purpose of this analysis, may be assumed constant. Hence to minimise the total cost due to man and material movement, the sections need to be arranged in such a manner that the distance travelled by the people or product between the time it enters the processing plant till the time it is dispatched will be minimum. The same approach can be thought of the movement between equipment in a particular room or department. In other words, our objective will be to find out particular D_{ij} combinations for minimising C.

Generally we proceed as follows:

- Determine the number of trips between each pair of sections per unit time such as a day, week, month or year, and with this information draw the ***trips matrix***.

- Ascertain the costs of material handling per unit of distance and draw the ***cost matrix***.

- Draw the ***distance matrix*** with the knowledge of distance between each pair of sections. These distances will depend on layout chosen.

- Compute the total materials handling cost per each pair of sections with the help of above three matrices.

The following example of Figure 13.6 will help you understand how this can be done.

Let us take the example of a small food processing plant, which has only five sections. In the first matrix, I have shown the number of trips required per week between each pair of section for a fixed quantity of raw material (Figure 13.6). Say for example, there will be 23 trips between sections 2 and 3, and 26 trips between sections 3 and 5.

I have put the costs of material handling per unit of distance between each pair of sections in the 2nd matrix. Subsequently on the basis of the layout plan, I found the distance between each pair of sections, and substituted the values in distance matrix.

It will be interesting for you to see that the **total cost matrix** is computed by multiplying the corresponding figures in the trips matrix, cost matrix and the distance matrix. Observe in Figure 13.6 that for sections 2 to 4 the cost of materials handling is (22)(23)(5) = Rs. 2530. After I have calculated all costs, I added all cells in the total cost matrix to get the total cost as, C = Rs. 38561 per week. This completes the evaluation of the equation for a particular layout plan.

Sections	1	2	3	4	5
1		24	25	27	24
2			23	22	24
3				25	26
4					27
5					

Trips matrix

Sections	1	2	3	4	5
1		32	23	34	42
2			30	23	21
3				18	23
4					20
5					

Cost matrix

Sections	1	2	3	4	5
1		5	7	8	4
2			6	5	4
3				7	8
4					5
5					

Distance matrix

Sections	1	2	3	4	5
1		3840	4025	7344	4032
2			4140	2530	2016
3				3150	4784
4					2700
5					

Total cost matrix

Figure 13.6: Computation of total cost of man and material movement for a layout plan

After this step, we may think of improvements by exchanging pairs of sections, and recalculating the total cost again. Alternate combinations of the locations, i.e. every possible layout are evaluated to find out the optimal solution.

In the above example of Figure 13.6, we have only 5 sections, and hence, we have only 4! combinations, i.e. only 24 arrangements are possible. However, as the number of sections increases the possible combinations would increase. For example with a plant having 8 sections the number of possible combinations will be 7! or 5040. You calculate yourself what will be the possible combinations for a plant having 20 sections. In such cases the use of a computer becomes inevitable.

13.6 MAINTENANCE OF CLEAN WORKING ENVIRONMENT

Cleanliness is very essential in any food processing establishment. It aims at protecting the food safety as well as improving and maintaining the quality of food. It is also the key to good health and efficient work. It is not only the responsibility of the plant manager to take care of sanitation aspects during operation, but proper layout, suitable placement of equipment, proper construction of building, doors, windows, selection of building materials etc. are also vital in maintaining a clean working environment during the plant operation. What do you do to remove bad gases or odours during cooking? The answer will be to switch on the exhaust fan or open the windows. But if the kitchen has no provision of exhaust fan/ventilator or windows, then what shall you do? It is the fault of planning the kitchen that the cook will suffer.

So, we should think about sanitation from the preparation stage of building plan. Provision of built-in sanitation in the construction design as well as in every piece of equipment, fittings, fixtures and utilities help us in maintaining a clean working environment. If the work area is not properly planned, the employee may tend to overlook hygienic practices while handling food. For example, if the wash basin is at a considerable distance from the working table, the worker may tend to skip proper washing of hands when required. There should be sufficient space to provide convenience and comfort to workers.

While selecting a site, we must have taken care that the area should be at a considerable distance from other industries, which might cause pollution. But after selecting the site also, we must be very careful for maintenance of clean environment within the industry and its vicinity. As discussed previously, we should isolate the areas/equipment producing dust, fumes, etc., so that they would not pollute the other working places. The processed food area should be kept away from the raw food area, receiving and cleaning sections. For example, if ginger or turmeric is collected directly from the field, then the washing operation should be carried out in a separate room or in an open yard away from the main room. The drying yard should not be kept near to the road or dusty areas. We should install the grinding mills or cyclones collecting powders in a separate room, or else, it will make the whole environment dusty.
In the ceiling if there are exposed beams or girders of iron or reinforced concrete, they would harbour dust and dirt. These dust and dirt get into the plant atmosphere and contaminate both equipment and products. The best ceiling is therefore one with a plain smooth horizontal surface. Light fixtures embedded or inset into the ceiling are more sanitary than the suspended ones. Windows must be properly constructed and maintained to provide adequate light and ventilation. The panes, frames, and screens must be easily and regularly cleaned. The doors and windows must be fly and rodent proof.

Smooth surfaces on the floor and glazed surfaces on the walls up to a height of at least 150-200 cm are satisfactory from sanitation point of view. Drains with proper slope should be provided in all rooms to carry away the liquid wastes promptly from the main working areas. Suitable slope of the floor helps easy cleaning. Garbage dumps and stagnant water in the vicinity encourage breeding of rodents, flies and mosquitoes, and hence should be at a considerable distance from the working areas.

13.7 WORKERS' SAFETY

Safety of workers is one of the prime concerns of any type of industry, and as mentioned in the preceding section, safety considerations start even from the stage of layout planning. Some of the important points that can be considered for workers' safety during designing of a food processing plant are as follows:

- There should be adequate space around all working equipment including those used for material handling to avoid collision between workers and the equipment and between workers themselves. This is more important for equipment, which need frequent servicing.
- The foundation and structure of the floor must be capable of supporting equipment, especially large storage tanks, work load and traffic.
- In the processing plant, fruit juices may fall on the floor throughout the processing area. If the floors have pores, cracks, joints then these get deposited on the floor and ferment to produce acid. The acids react chemically with the floor materials, corroding and damaging the floor. Hence, all parts of the food processing plant should have suitable acid resistant floors. The floors should also be able to tolerate physical abuse and thermal shock.
- The surface of the floors must not be slippery. However, rough surfaces are not preferred as they are difficult to clean; hence we should give a suitable slope to the floor for proper drainage. The design of the drains must permit quick flow of effluent. Drains should be covered with grills or perforated grate, which are inset and level with the floor. This allows normal traffic across a floor area without interference by the drains.
- We should assure proper lighting to all parts of the plant. The areas where there is more chance of water pouring onto the floors or the moist areas need special attention.
- The dangerous and moving parts of the machines need to be fenced. The places where the persons are likely to fall as dangerous pits, sumps, openings in floor, etc. should also be fenced. There should be provision for suitable safety devices in the moving machines so that they can stop immediately if any problem occurs.
- During operation, untrained and unskilled workers must not be allowed to operate any machine or equipment.
- There should be provision of emergency doors for escape in case of fire, necessary fire fighting equipment and training to workers.
- Proper maintenance measures should be taken for each and every machine and periodic routine checkups are essential to avoid accidents.

Safety is a matter of concern for all directly or indirectly involved in the industry, and small cares taken for maintenance of a better work place and during operation can help prevent major accidents and improve the performance of the food processing plant.

13.8 REGULATIONS AND STANDARDS

The Factories Act, 1948 is applicable to all types of food processing industries. The main objectives of the Factory Act are (i) to regulate working conditions in factories; and (ii) to ensure that basic minimum requirements of safety, health and welfare of the factory workers are provided. Besides, the Act envisages regulating the working hours, leave, holidays, overtime, employment of children, women and young persons, etc. The revision of the Act in 1987 included rules for use and handling of hazardous substances and procedures for setting up hazardous industries. The State Governments are empowered to make the rules for ensuring the administration of the provisions of the Act in their respective states. The occupier of a factory is required to get prior approval of the State Govt. for the site on which the factory has to be situated. The Chief Inspector of Factories is responsible for the approval. The occupier of the factory is also required to get the factory registered for obtaining a license for operating it and send a notice of occupation to the Chief Inspector of Factories, at least 15 days before it begins to occupy the factory.

Some important aspects of the Act as regards to health, safety and layout aspects are as follows:

1. Maintain all places of work in a condition that is safe and without risks to health.

2. Make arrangements for ensuring safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances.

3. Fencing of all dangerous and moving parts of the machinery while in motion or use.

4. Providing sufficient space for workers to operate self-acting machines; encasing and guarding of all machinery installed in the factory and every set of screw, bolt, spindle, wheel or pinion so as to prevent danger

5. Taking necessary steps to ensure that the maximum safe working peripheral speed of every revolving machine, etc. and the maximum safe working pressure of any pressure plant are not exceeded.

6. Keeping floors stairs, steps, free from obstructions and slippery substances and providing with substantial handrails, wherever necessary.

7. Providing suitable striking gear or such device for the movement of driving belts of any transmission machinery and proper locking of device which can shift inadvertently from 'off' to 'on' position.

8. Ensure that workers do not overcrowd the workplace. There should be a provision of minimum space of 14.2 m^3 per worker in a new factory and 9.9 m^3 per worker in an existing factory. Suitable provisions for lighting, drinking water, latrines, urinals and spittoons are also covered under the Act.

Besides, as I have mentioned previously, there are specific standards for ergonomical considerations for design of equipment or arrangement of workspace. Some more standards related to maintenance of clean working environment come under the Pollution Control Laws.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. How does the analysis of man and material movement help in layout planning of a food processing industry?

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2. What is the need to have enough working space around the equipment?

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3. Write True / False:

   a) In a fruit and vegetable processing plant, the processed food area and raw food area should be kept close to each other.

   b) The drying yard should be kept close to the roads.

   c) The floors of a food processing room should be made rough to avoid slipping of the workers.

13.9 LET US SUM UP

In this unit, we have studied the various aspects of site selection and layout of a fruit and vegetable processing plant. We began with the factors affecting site selection and plant layout and then discussed the general considerations for a food plant layout. We discussed some rules for layout of different buildings, equipment, service facilities and waste disposal systems. We also studied the different steps involved in a layout planning process. How the analysis of man and materials movement, cleanliness and safety affect the plant layout are also discussed here. The unit has acquainted you with the general principles of site selection and plant layout, which are the primary steps in planning any type of industry.

13.10 KEY WORDS

Plant layout : Physical arrangement of the industrial facilities

Line flow process : When the product flows from one operation to the next in a prescribed sequence

Intermittent flow process : When the production is carried out in batches at intermittent intervals. We can organise the equipment and labour into different work centres by similar types of skill or equipment

Process form of layout : The intermittent process is also known as process form of layout as similar equipment and processing operations are grouped together.

Product layout : The line flow is also called a product layout because various process equipment, and labour skills are put into sequence according to the way the product is made.

13.11 SELF TEST FOR THE COMPLETE UNIT/ ASSIGNMENT

1. Describe the different guidelines for layout of different buildings in a food processing plant?
2. Describe the different guidelines for layout of different equipment in a food processing plant?
3. Explain the different steps that can be taken during layout planning for maintenance of clean working environment and workers' safety?

13.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. The major factors for selection of site for a fruits and vegetables processing plant are availability of raw material and good quality water, good surroundings, availability of electrical power, good transport facilities, easy availability of labour, facilities for disposal of wastes and scope for future expansion.
2. A good plant layout has the following advantages: saving in floor space, better utilisation of machine, manpower and services, reduced material handling, reduced inventory in process, increased output/ production per unit time, labour, money and energy, easier and better supervision

Check Your Progress Exercise 2

1. The basic objectives of a good plant layout are smooth operation and reduced cost in handling and processing.
2. If during the preparation stage of a plant layout, possible future expansion is not considered, we will face problems in expanding our industry or business, either by addition of new products or by increasing the capacity.

3. The layouts can be process form of layout and product layout. Also hybrid layouts, which are a combination of the above two are possible. The layout can also be classified as single level, multi-storey or combined layout.

4. Three dimensional scale models give a better representation of relative positions of different equipments and spaces than the two-dimensional drawings. In bigger models, the piping and utilities can be shown, which give idea on the actual work area that will be available.

Check Your Progress Exercise 3

1. The analysis of man-material movement helps to select a layout among many possible alternatives, which will reduce the total cost of movement and materials handling within the plant. This helps in minimising the cost of operation of food processing industry.

2. There should be adequate space around equipment to avoid collision between workers and the equipment and between the workers themselves. This will also help in servicing of the equipment.

3. a) False
   b) False
   c) False

13.13 SOME USEFUL BOOKS

1. Reed, R. (1961). Plant layout-Factors, Principles and Techniques. Richard D. Irwin, Inc. Illinois.

2. Vilbrandt, F.C., Dryden, C.E. (1959). Chemical Engineering Plant Design. 4th Edition, McGraw Hill Tokyo.

UNIT 14 EQUIPMENT AND MACHINERY

Structure

14.0 OBJECTIVES

After studying this unit, you should be able to:

- know how the equipment are selected, installed and maintained in a food processing plant;
- visualise how the different ergonomical factors influence the design and arrangement of equipment and work area; and
- acquaint yourself with different managerial skills such as proper maintenance planning, management of inventory of spare parts and good manufacturing practices, which help in improving the performance of equipment and workers in an industry.

14.1 INTRODUCTION

In this unit we shall discuss about the different factors for selection of equipment for a fruit and vegetable processing plant. You will observe that the entrepreneur can himself decide the type of equipment with a proper understanding of different unit operations that are to be carried out in the processing plant. Then we will discuss how the human factors such as body posture, selection of tools, environmental factors, etc. affect the selection and installation of different equipment and improve the work efficiency. You will also know about the different maintenance and inspection schedules, workers' safety and spare parts management aspects. Our basic objective in this unit will be to understand the skills needed to upkeep the operational area and equipment, minimise the plant downtime, and to improve overall performance of the setup.

14.2 SELECTION OF EQUIPMENT

In the previous unit, we discussed about the plant layout and how a proper plant layout helps in maximisation of profits. After we have decided the process, prepared a good plant layout, and have constructed the building as per requirement, the next job is the selection of equipment and their installation. In fact these considerations start even before the civil construction work is started. We must remember that the equipment constitutes a major part of the initial investment and if not decided properly, may create problems in future. The problems could be of many types, such as low performance than rated capacity or frequent disorders. Sometimes the workers do not find the equipment comfortable to work with. Therefore, we must be very careful for selection of each individual equipment for the processing plant.

14.2.1 Selection Procedure

The selection of the types and sizes of equipment for the process plant requires considerable experience. However, as most of the food processing operation that we will be dealing with are established ones and are in operation elsewhere, the task becomes chiefly of comparative evaluation of standard equipment available from different manufacturers, scaling of the equipment and accessories up and down, and incorporating pertinent improvements that previous users have suggested.

First, we have to list the required equipment from engineering flow sheets. The next step is to make the necessary design calculations with the help of an expert and prepare the specifications for each equipment. The equipment not only include the major processing equipment and boilers, but also other accessories as suitable weighing scales, small hand tools, sieves, basins, buckets, and quality assurance equipment. If outside bids are required, detailed specification sheets must be presented to suppliers.

Standard vs. special equipment

We may use standard equipment already available in the market, or may design and fabricate equipment as per our need. However, use of the standard equipment is always better as it has the following advantages over the specially fabricated equipment.

- The initial investment for standard equipment will be significantly lower as compared to the special equipment.

- The duplication of equipment is easier.
- The repair and maintenance are easier and standard spares are easily available. Most often the equipment comes under a guarantee of satisfactory performance.
- Standard equipment has gone through long periods of experimentation and has been tested elsewhere. Usually it is the result of many modifications of its original design.

Hence, unless it is absolutely necessary, we should not be involved in the design of equipment. When we are sure that we have completely exhausted the trade literature for our requirements, then only we should think of design of a special equipment.

Specifications and competitive bidding

As we discussed earlier, a range of equipment for almost all types of operations in any food processing plant are available; our job is to specify our requirement for a particular duty and then select suitable machines from the above range. The specification should contain all essential information such as characteristics of the material handled, kind and quality of service requirements, delivery requirements and quotation. A comparison of the different machines available in the market often helps our decision with respect to principal components, materials of construction, service requirements, and accessories furnished along with the cost. Minor modifications may be suggested for an equipment for particular applications. We must also consider the delivery time, experience, and reliability of the supplier before final selection of the supplier.

14.2.2 Example of Selection of Equipment

Standard guidelines for selection of different types of process equipment are available in different *Chemical Engineers Handbooks*. For a general understanding of these guidelines, we will discuss about the selection of a dryer in the following paragraphs.

Drying equipment can be classified according to the following design and operating features.

1. Batch or continuous.
2. Physical state of feed: liquid, slurry, wet solid.
3. Method of conveyance of the solid: belt, rotary, fluidised.
4. Heating system: conduction, convection, radiation.

Dryers can be either batch type or continuous type. Batch dryers are normally used for small-scale production and where drying cycle is likely to be long. Continuous dryers require less labour, less floor space and produce a more uniform quality product.

The choice of suitable drying equipment cannot be separated from the selection of the upstream equipment feeding the drying stage. The main factors in the selection of drying equipment are the nature and concentration of the feed. For example the dryer to be selected for drying tomato paste will be different from the dryer for drying peas. For the first case a drum or spray dryer is considered suitable, and in the second case a fluidised bed dryer is better as it gives a more uniform product with higher drying rate for particulate solids.

In general with solids feeds, the material should be placed in the drying chamber in such a way that it will produce a bed of solids with an open, porous structure. For pastes and slurries, some form of pre-treatment such as extraction or granulation is often needed.

Besides the feed condition and the initial liquid content, the other product factors, the required quality of the end product such as its physical form and dryness, and the heat sensitivity of the product also play a major role in selection of the dryer. Hot air is mostly used as drying medium in industrial dryers. The air is directly heated by electrical heating coils, gas or oil, or indirectly heated, usually by banks of steam-heated finned tubes.

A range of dryers is available for use in a food processing industry, viz. tray dryers, conveyor dryers, rotary dryers, fluidised bed dryers, pneumatic dryers, spray dryers, drum dryers, infrared dryers. Our type of dryer should be picked from these available types depending on our requirement. After the type of dryer to be installed has been decided, the capacity of the dryer is decided based on the throughput required.

14.2.3 Other Considerations

After a brief discussion on some general guidelines, some more points that need consideration before making the final selection for any equipment are:

- How many operators are required to operate the equipment and the kind of technical knowledge they must possess?
- Whether servicing the equipment needs outside technicians or can it be serviced by available staff?
- What is the power consumption of the equipment?
- Whether the equipment can be easily cleaned and sanitised?
- What is the durability of the material used in the equipment?
- Whether the equipment is silent or noisy when operating?

14.3 MOVEMENT AND INSTALLATION OF EQUIPMENT

In our every day experience we observe many physical equipment and facilities, which are not suitable to use because of their installation features. Examples include kitchen sinks that are too low, uncomfortable chairs, narrow staircases, very little space near a equipment that needs repair, and so on. Therefore, installation of the equipment is as important as the selection of proper equipment.

In most of the cases the manufacturers take up the responsibility of proper packing of the equipment so that it does not damage during transit. The movement within the plant is done by labour or by trolleys or cranes. They may also take up the installation job with or without charging an extra amount. However the plant manager has the responsibility to check that the machine/equipment is properly installed for convenient working, cleaning and maintenance operations. The machine should have a proper foundation. In particular the machines which produce significant vibration and noise should have a proper base. Sufficient working space should be kept around the machine.

Almost all equipment are designed for standard people. But installation is very important for comfortable working for a special group of people. The physical location and arrangement of such items (and of their specific features) can affect the comfort of the users as well as physical well being. For example, the comfortable working height of the tables and control panels will differ for ladies and gents. Therefore, special care should be taken during installation of equipment, working tables, etc. which could ultimately affect the work performance.

14.4 ELECTRICAL WIRING

A factory generally needs 3 phase 4 wire supply. For motors whose ratings exceed 2 or 3 kW, 3 phase 3 wire supply is required; and for light and fan circuits single-phase supply is required.

For internal wiring for supply to motors, conduit system of wiring with vulcanised Indian rubber (VIR) or PVC insulated cables of suitable size are used. The conduits are usually run on surface rather than laying them in covered trenches to facilitate additions and alterations. Use of separate conduit for every motor is preferred. The conduit used in power wiring should be electrically continuous throughout and connected to the frame of the motor. The frame of the motor is to be earthed by two separate and distinct connections to earth. Under-ground cables are preferred for very large capacity motors.

In domestic installations single earthling is sufficient but in an industry double earthling of motors, medium voltage regulating or controlling equipment etc. is necessary. Circuits and sub-circuits to 400 V motors must be provided with fuses on all poles, i.e. on all three phases of the a.c. supply.

In a large industry, power distribution is made from a suitable location, known as distribution centre, through a switchboard. This switchboard consists of a set of insulated bus bars. Each incoming and outgoing circuit is controlled by an automatic circuit breaker (or linked switch and cutouts). The outgoing circuits feed different sub-distribution boards erected at convenient places, which further distribute power to a number of equipment. A line diagram, showing the tapping supply from bus bar chamber to the individual machine is shown in Figure 14.1. In small industries, sub-distribution boards are not needed and a switchboard or distribution board is used for distribution of power. All equipment used in power wiring should be of iron clad construction and wiring shall be of the armoured cable or conduit type. Every motor, regardless of its size, shall be provided with a switch fuse close to it, and with a suitable starter placed at a convenient place. The starters are used to limit the starting current to a desirable value. Electrical wiring diagrams must be prepared for all sections and a qualified/trained personnel should be given the responsibility of electrical wiring of the complete plant.

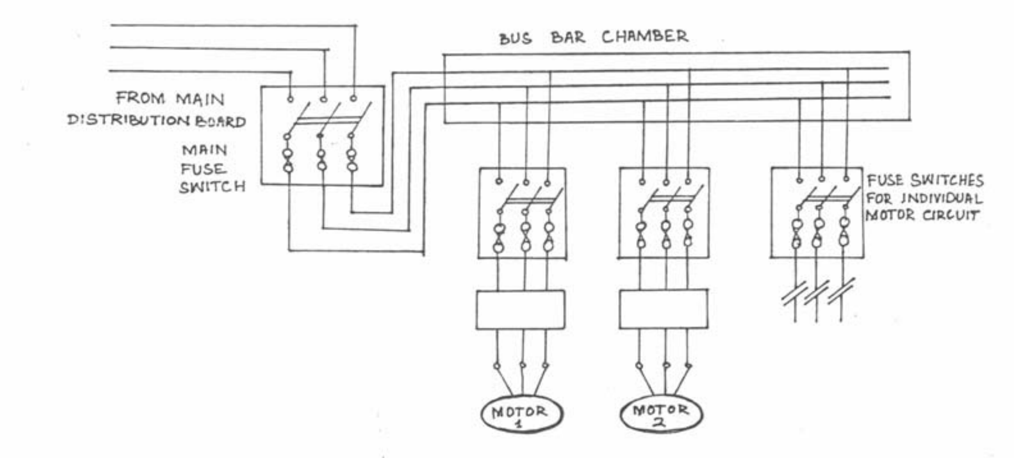

Figure 14.1: Supply from busbar chamber to individual machines

14.5 ERGONOMIC CONSIDERATIONS

The word ergonomics is derived from the Greek words 'ergon' (work) and 'nomos' (law). In the United States, the term 'human factor' is used for ergonomics. It is defined as the scientific discipline concerned with understanding the interactions among humans and other elements in a system, and the profession that applies theory, principles, data and methods to design, in order to optimise human well being and overall system performance. In other words ergonomics aims to design appliances, technical systems and tasks in such a way as to improve human safety, health, comfort and performance at work and everyday life. Motivating the man at work and making the work to suit him is the prime objective of ergonomics.

The application of ergonomics includes plant and workspace layouts, selection, training and placement of personnel, design of equipment, power tools, displays, jigs, fixtures, and even furniture, motivation of the worker, working conditions and environments, and computation of relaxation allowances.

The ergonomical factors include body posture and movement (standing, sitting, lifting, pulling and pushing), environmental factors (noise, vibration, illumination, climate, chemical substances), information on different machines and operational characteristics (information gained visually or through other senses, controls), as well as work organisation (type of task, nature of job, etc., whether the job is interesting or not?). Brief descriptions on these factors is given below.

14.5.1 Body Posture and Movement

Posture and movement play a vital role in ergonomics. Poor design or installation of equipment, technical systems and tasks has often reported to cause back pain, psychological illness (e.g. stress) and occupational disability. In addition, it also reduces performance and sometimes leads even to accidents. Some of the ergonomic considerations may be that the important components should be placed in convenient locations. The body size of the workers should be kept in mind for designing the working tables. Particularly the assembly tables and packaging section need special attention as in a food processing plant the workers need to stand or sit at a constant place for longer times. During movements, the body joints ought to be kept as far as possible in a neutral position. The workers should not be overloaded during conveyance of loads. Lifting accessories like lever, raising platforms and cranes and transport accessories such as conveyor, sack barrow, mobile raising platform, forklift, etc. should be used wherever possible.

14.5.2 Environmental Factors

The environmental factors such as noise, vibration, lighting, and climate can affect people's safety, health and comfort. The chemicals do also affect. The presence of high noise levels during a task can be annoying and prolonged exposure can result in impaired hearing. The noise level should be below specified levels; in most cases it is 80 decibels.
Ensure that floors are hard and even, and machines have proper foundation. It not only reduces vibration and noise, but also avoids other types of accidents. Well-maintained machines are quieter. There must be proper illumination in all parts of the factory. The air temperature, humidity and ventilation affect the comfort and productivity of the workers. The location of the building and its surroundings, convenience of transportation, size and number of rooms, design of ceiling heights and slopes, windows, style of architecture, type of building materials, colour, cleanliness, etc. are considered under environmental factors, which affect the work performance.

14.5.3 Information and Operation

The workers should be well informed about the work they are doing, with their important contribution in the work. They should feel responsible for their role in the final product development. This way they will be more involved in the work and their performance will increase. Suitable warnings at desirable places, display of the steps of operation and maintenance of the machines, putting different colours for different switches, etc. are some ways to improve the performance of equipment and workers, and reduce accidents.

14.5.4 Work Organisation

The worker must find the equipment comfortable, and he must enjoy the technical systems and tasks, which can be achieved by proper work organisation. Selection of the right kind of tool come under this category. Suppose we use a dull knife in cutting of vegetables, we expend a lot of extra energy that is, in effect, wasted. It is also important to train the workers on the proper way of using the tools. Further, the tools can not be designed in isolation. Often a redesign of the workspace, which includes the work envelope, work surfaces (such as desks, tables, etc.) and seats (if used) as well as the design and relocation of equipment used. The important components need to be placed at convenient locations.

You must bear in mind that safety can be improved by 3 E's, viz. education, engineering and enforcement. A range of ergonomic subjects is covered by international ISO standards, European EN-standards, as well as national standards. In addition, there are specific ergonomic standards, which are applied to individual companies and industrial sectors. These should be followed for the overall effectiveness of the industry.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the advantages of standard equipment over special equipment?

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2. What are the main ergonomic considerations during arrangement of work space and design of tools?

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14.6 UPKEEP OF OPERATIONAL AREA

Proper upkeep of operational area improves performance of workers and increases production. A systematic and scientific maintenance of operational area assures instant operational readiness and optimal availability for production at all times without compromising on the safety of man and machine. It also reduces worker frustration and improves job satisfaction, which in turn improve the working life of personnel, and productivity.

The health and safety of both workmen and machines need careful maintenance. This is more important for a fruits and vegetables processing plant where they affect food safety. The orderliness and cleanliness of the workplace has to be assured to improve total productivity and the conditions of the labour force, and to avoid accidents. There should be proper light and aesthetic environment.

For most projects, a maintenance planning system is included in the preparation stage of the project to protect the investment in machinery, plant and buildings through regular and adequate maintenance. These all help in reduction in downtime, which is very significant in a food processing plant, as we have the responsibility to process the produces within the shortest possible time after harvest. Further, with ever increasing cost of labour and material, this is good economy also. It maximises the utilisation of labour and other resources and prevent waste of spares, tools and materials.

14.7 MAINTENANCE AND INSPECTION SCHEDULE

14.7.1 Maintenance Scheduling

You must have experienced the importance of scheduled maintenance for the performance of any machine. For example, we change the gear oil of our motorcycles after every 3000 km of running as a scheduled maintenance practice. A **maintenance schedule** is the sequential arrangement by which maintenance is done. In an industry, the schedule indicates, what is the work to be done, how often it is to be done, by which it is to be done, and the estimated time required to complete the work. Separate schedules have to be prepared for each type of maintenance activity, and for each equipment/machine.

The decision on a sequence is based on the priority, the availability of spares, materials and specific tradesman. It should be remembered that most critical equipment has to receive prompt attention in maintenance caring and should be the first items to be scheduled. The other priorities could be emergency breakdown, preventive maintenance, predictive maintenance, and/ or other maintenance systems prevalent in the organisation.

The guideline for the maintenance are often laid down by the manufacturer. But the actual conditions of operation, the severity of use, and the skill level of operators are also to be considered. Schedules must be made in two parts: the **long term schedule** to be made 8-12 weeks in advance, and the **short term schedule**, just a week or two in advance. This will help in preparing and planning in advance for materials, spares, tools, and test equipment. The short-term schedule is finally broken up into daily schedules for day-to-day implementation and for assuring that close control would be exercised. The supervisor assigns work individually to each worker and keeps him informed as to what work is expected of him within a small frame of time limit, may be the next morning. This allows the worker to plan his own activities. Revisions in schedules are expected, and hence, they must be kept flexible enough to accommodate any change.

14.7.2 Inspection Scheduling

Inspection is the examination of equipment and machines or their parts to determine their condition. Periodic inspection helps detect extent of deterioration and plan for its repairs and rectification, or if need be, even make replacements before an actual breakdown occurs.

Take for example the daily inspection routine for a fan or a pump would involve carrying out checks for:

a) any abnormal vibrations, or any abnormal noise;

b) the temperatures of all the bearings to ascertain that they are at acceptable levels and that there is no overheating;

c) leakages from the glands and gauge to see whether they are excessive;

d) oil levels in cups; and

e) grease nipples to ensure that they are not dry.

Different checklists are required for the same machine, depending on whether the machine needs a weekly, monthly or annual check up.

The frequency of inspection is affected by many factors, such as:

a) age of the machine or equipment, its condition and value;
b) severity and intensity of service;
c) hours of utilisation- are they prolonged- or intermittent;
d) susceptibility to wear and tear or any other damage;
e) susceptibility to losing adjustment during use- Will the maladjustment and non-alignment affect the accuracy or functioning? Will the lack of proper balancing affect performance?
f) safety requirements and considerations;
g) criticality of item- if the item is very critical, then it may need daily inspection.

14.8 PERIODIC MAINTENANCE PRACTICES

14.8.1 Classification of Maintenance System

The different maintenance systems can be classified as: a) Breakdown maintenance, b) Routine maintenance, c) Planned maintenance, d) Preventive maintenance, e) Predictive maintenance, f) Corrective maintenance, g) Design out maintenance, h) Total productive maintenance, and i) Contracted out maintenance.

Breakdown maintenance or repair maintenance is carried out only in case of a need of repair or when the machine ceases to work. **Routine maintenance** involves routine checks such as daily lubrication and inspection of the machines, monthly inspection of motors. **Planned maintenance** is maintenance organised and carried out with a predetermined plan depending on the machine's needs, expected requirement of the machines and manufacturer's recommendation.

Preventive maintenance system refers to the steps taken to reduce the likelihood of failures to the absolute minimum. **Predictive maintenance** can be defined as "methods of surveillance used to indicate as to how well the machine is, while performing its intended tasks". **Corrective maintenance** is defined as maintenance carried out to restore (including adjustment and repair on item) machinery, which have ceased to meet an acceptable condition. **Design out maintenance** (DOM) tries to eliminate or to minimise the need for maintenance to the lowest possible level.

The basic concept of **total productive maintenance** is to change the attitude and improve the skill of all personnel by using quality equipment. **Contract maintenance** is using specialised maintenance personnel on contract basis, mostly for specific equipment.

Each individual organisation, big or small, simple or complex, or using highly advanced or simple technology must choose the maintenance system that suits it best. Total maintenance planning includes: a) inspection, b) lubrication, c) planned maintenance, d) preventive maintenance, e) predictive maintenance,

f) corrective maintenance, g) modifications h) retrofits, i) refurbishing, j) overhaul, k) replacement of equipment, l) discarding of equipment, m) standardisation, n) material requirement planning, o) spares planning, p) documentation, q) spare parts manufacture, r) exercising of spare parts and sub-assemblies held under long term storage (Particular attention should be given to rubberised components).

14.8.2 Maintenance Steps in a Fruit and Vegetable Processing Plant

In general the maintenance steps for a general food processing plant includes following steps.

- Carry out a visual check of the equipment and all operational area for cleanliness.
- Check if safety devices are present and functional. If not, do not operate the equipment.
- Operate the machine and check for any unusual noise, vibration, friction and instruction.
- Check if lubrication cups are replenished to correct levels and grease nipples so that they are not dry; then operate the machine. This is mainly required for conveying machines and elevators.
- Never operate the machine beyond laid down conditions of speed and feed.
- Make sure that no tools or any smaller parts of containers, glass pieces, etc. have dropped inside any equipment.
- Follow the manufacturer's recommendations for maintenance of each individual equipment.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How proper maintenance and inspection help improve performance of a food processing plant?

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2. What is a maintenance schedule?

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14.9 INVENTORY OF SPARE PARTS

An **inventory** is a stock of materials used to facilitate production or to satisfy customers. All idle resources other than materials are considered as capacity, e.g. equipment or idle workers. Capacity is used to produce, while inventories are the products at some point in conversion and distribution process.

Spare parts are those parts of machines, which because of wear and tear, use or breakage, need replacement. However, it is often not possible to obtain each and every spare in the market as and when needed. Besides, purchasing anything in small quantity is expensive also. There is also chance of getting improper spares. Hence it is necessary for any industry to carry inventories of frequently used spare parts. In particular, in a food industry when the work is in progress inventories of spares are an absolute necessity.

The finance department generally prefers to keep the inventory level low to conserve capital, marketing prefers high levels of inventories to enhance sales, while operations department prefer adequate inventories for efficient production and smooth employment levels. Inventory management must balance these conflicting objectives and manage inventory levels in the best interests of the factory as a whole.

The decision problems in inventory management are a) which items should be carried in stock, b) how much should be ordered, c) when should an order be placed, d) what type of inventory control should be used. Whether to buy a spare or make it in the workshop / local market is another criteria. This decision is dependent on the cost, assurance of availability, opportunity to control quality, availability of equipment and expertise, desire to preserve confidentially, and saving in transportation costs.

14.9.1 Optimisation of Total Cost of Inventory

What is the quantity to be purchased is one major decision in inventory management. The **economic order quantity (EOQ) model** is a tool, which helps to know the quantity that will optimise the total cost. The motivating factor to control inventory is the cost incurred by carrying it. The different costs involved in the calculation of the total cost are:

1. **Item cost** or the cost of buying or producing the items;

2. **Ordering** or **setup cost,** which is the cost of getting an item including the cost of transportation, and salary of personnel working in stores and stock verification department;

3. **Carrying** or **holding cost,** which includes capital cost, storage cost or rents, depreciation charges, cost due to deterioration of the part or obsolescence; and

4. **Stock-out cost**, which reflects the economic consequences of running out of stock, since the sale is lost if material is not on hand. The profit is lost on sale, and good will in the form of future sales.

The quantity, which optimises total cost, is known as **economic order quantity (EOQ)**. For a general case, EOQ is given by,

$$\text{EOQ} = \sqrt{2C_o M/(C_c p)},$$

where, C_0 is the order cost or setup cost, Rs. per order,

C_C is the carrying cost, expressed as percent of Rs. values per year,

M is the annual consumption, units per year, and

p is the unit price, Rs. per unit.

We will see the applicability of this formula with the help of a small example. A fruit processing plant purchases 600000 bottles per year for handling juice. The order cost is Rs. 70 per order, and the carrying cost is 15% per year. If each bottle costs Rs.2 only, find out the economic order quantity?

Solution

$$\text{EOQ} = \sqrt{2\frac{(70)(600000)}{(0.15)(2)}} = 16733 \text{ units.}$$

It means that the plant should purchase 16733 bottles at a time. This will result in 600000/16733 = 36 purchases per year, i.e. one purchase almost in every 10 days. This quantity will involve minimum total cost for maintaining the inventory. Now, check that if the order cost is increased to Rs. 210 per order, the EOQ will be 28983, i.e. the plant has to purchase 28983 bottles in each order to minimise the total cost. In that case it will go for 20 purchases in the year.

We suggest you to change the unit price and other parameters and see how these changes affect the EOQ. You will observe a definitive change in the EOQ with changes in the above parameters. Even though the EOQ model has several limitations as it assumes a constant demand, a constant unit price, a constant setup cost, etc. throughout the year, still it is widely used in the industry as a standard tool for the inventory management.

14.10 MINIMISATION OF EQUIPMENT DOWNTIME

As we have already discussed, the downtime for any equipment or for the complete plant can be reduced by proper upkeep of operational area, by properly scheduling the maintenance and inspection, and judicious management of the inventory of spare parts. In this section we will give a closer look at this area.

14.10.1 What is Downtime?

Downtime in general may be considered as the time when the plant or any specific equipment is down or not performing. Thus the downtime directly affects the production. However, downtime does not always imply / cause a direct production loss. There are certain conditions under which downtime does not create a production loss, e.g. when the plant does not operate at full capacity utilisation level, or when the completely processed product is not lifted for delivery to customers but is stored.

14.10.2 Reasons of Downtime

The main reasons for downtime in an industry or a section are as follows:

- Breakdown of a machine due to any reason.
- Failure in power supply or load shedding.
- Non-availability of suitable raw material.
- Improper planning, scheduling or machine loading.
- Lack of proper tools, jigs or fixtures.
- Non-availability of calibrated test equipment.
- Shortage or absence of operator.

14.10.3 How to Reduce Downtime

Once we know the different possible reasons for downtime in our plant, the planning to reduce the downtime becomes much easier. Both the operator and the maintainer have to jointly make efforts to lower and control down time.

Simple dos and don'ts are to be specified for an operator, which if followed can eliminate a large number of breakdowns. For example, before the start of the machine the operator should check all the safety devices, lubrication points and cleanliness. Then he should operate the machine for a short time to check for the presence of any unusual noise, vibration, friction, etc. The management should have the responsibility to educate and train the workers on these aspects.

Some basis steps that are useful in reduction of downtime are as follows:

- Adopt proper maintenance planning, maintain and carry out repair of buildings, utilities and allied equipment.
- Ensure scheduled inspection and lubrication of all necessary points
- Adopt rapid fault-finding systems and the use of diagnostic charts
- Ensure and carry out faithful recording and documentation of all maintenance work, and review of the records. Analyse repetitive failures of any particular equipment and replace the faulty parts / redesign the machine.
- Standardise equipment for replacement and purchase.
- Monitor procurement of spare parts and material for maintenance.
- Design and enforce safety standards.
- Recruit and train personnel to carry out maintenance work.

It is very important to record all breakdowns with care and absolute accuracy, so that the parts that have failed may be segregated and analysed to find out the reasons for the failure. Every single person working in the maintenance department must know his or her exact function. Once the cause has been diagnosed, corrective actions are to be planned and taken. We must understand that it is a collective job and all persons associated in the plant operation have individual important responsibilities for reduction of downtime.

14.11 MAINTENANCE OF RECORDS

It is very important for an organisation to maintain different records and document them properly. This is quite beneficial. For example, if the job cards and history record cards are properly maintained, one can choose machine or equipment wise information about how much has been the annual maintenance cost on each of them.

Facility register: A facility register is a complete list of all the machinery, plant, equipment and buildings, which have to be maintained. If the number of such items is very large, then they can be maintained in different groups depending on their usage, technical practices, or by the maintenance methods which are being used. For example, a food processing plant can be divided into sections by their maintenance needs. The shut down can be done section-wise for maintenance. This can help in working at all other sections while a particular section is undergoing maintenance. Such types of information are maintained either by cards or by computers.

Equipment record card: An equipment record card or **Plant record card** keeps all information about each individual machine, such as the name and address of supplier, date of purchase, price, etc. It is very useful when a repeat order has to be placed for procurement after many years and the necessary information is not available from any other source.

History record card: A history record card or **Log card** carries information on all corrections, replacements, repairs, and other modifications that have been carried out on a particular equipment from the day it was inducted to the day it is scrapped, or disposed of. If an equipment is moved from one section to another, its History record card has also to move along with it. The card is quite helpful in analysing the total downtime, the frequency of occurrence of specific faults, and which parts or spares are frequently being replaced. Thus it will help in making standardisations and replacement decisions.

Defect analysis record: This is another type of record, where the focus is on defect analysis.

Besides, the food processing plant has to maintain several other records related to financial and marketing departments, operation departments, etc., which help in the analysis of raw materials status, production status, money flow and similar factors of interest to the plant manager.

14.12 CERTIFICATION

In India, the fruit and vegetable processing industry come under the **Fruit Products Order (FPO)** issued by the Govt. of India. No person shall carry on the business of a manufacture except under and in accordance with the terms of an effective license granted to him. A manufacturer using different manufacturing premises for manufacture of fruit products shall take out a separate license from each such premises.

The FPO has many quality standards relating to production, quality of processed products, and packaging aspects. It also covers the **Prevention of Food Adulteration (PFA)** Act. FPO has standards for the sanitary requirements of a factory manufacturing food products. The 2nd part of the 2nd schedule has specifications for different types of processed fruits and vegetable products. This is just to acquaint you with the FPO. For details, I suggest you to go through the draft of the FPO.

You must have also heard about **International Organization for Standardization (ISO)** certification. At present there are two series: ISO 9000 series and ISO 14000 series. ISO 9000 is concerned with "quality management". This means what the organisation does to enhance customer satisfaction by meeting customer and applicable regulatory requirements and continually improving its performance in this regard. ISO 14000 is primarily concerned with "environmental management". This means what the organisation does to minimise harmful effects on the environment caused by its activities, and continually to improve its environmental performance. The vast majority of ISO standards are highly specific to a particular product, material, or process.

ISO standards contribute to making the development, manufacturing and supply of products and services more efficient, safer and cleaner. They make trade between countries easier and fairer. ISO standards also serve to safeguard consumers, and users in general, of products and services. This certificate is very useful to industrial and business organisations of all types, and to suppliers and customers of products and services in both public and private sectors.

There are several methods and tools to help with the implementation of a Food Safety Management System, such as **HACCP (Hazard analysis and Critical Control Points)**, **Good Hygiene Practice (GHP)** and **Good Manufacturing Practice (GMP)**. Together with a Quality Management System, e.g. ISO 9001, they form the basis for an overall Food Safety Management System.

Hazard analysis is the identification of all ingredients, stages in progress, environmental features and human factors that can lead to hazards for the customers. The risks and likelihood of their occurring is estimated. Critical Control Points are the points at which control is essential to guarantee that potential hazards do not become actual hazards. A CCP is a location, a practice, a procedure or a process, which if not controlled, can result in an unacceptable risk. Examples include inspection of goods at delivery or before use, correct temperature ranges during sterilisation or blanching, etc. Thus HACCP is preventive in nature and it protects the consumers from exposure to potential food hazards. Thus HACCP should be the top priority in any food firm.

A HACCP certificate proves that our food safety system has been measured against a best practice standard and found compliant. Issued by a third party accreditation body/registrar, the certificate proves to customers that we have implemented the necessary routines to ensure food safety. It is a prevention-based food safety system. It provides a systematic method for analysing food processes, determining the possible hazards, and designating the critical control points necessary to prevent unsafe food from reaching the consumer. HACCP is based on the Codex Alimentarius developed by the Food and Agricultural Organisation of the United Nations and the World Health Organisation.

14.13 GOOD MANUFACTURING PRACTICES

A food processing industry has the responsibility to make safe and wholesome processed food available to the consumers. In addition, it has to take care of the sustainability of the industry. Hence, good manufacturing practice (GMP) should look at the above two factors.

The aim of good manufacturing practice in the food industry is to provide food that meets the consumers needs and wants, and also to give them the security of safety ad reliability. GMP is based on the knowledge and skills throughout the food system, from primary production of the raw materials, through processing of the industrial ingredients, manufacturing of the consumer products, distribution of the final retail products till the cooking and eating of the final food. The objectives of GMP are to control the changes in the food materials so as to develop desired qualities in the product, to ensure that the food is safe to eat, and to stop or slow down any deterioration in the food. GMP means understanding, analysing and controlling the manufacturing process.

GMP guidelines include location requirements, design of facilities, facilities to be provided such as supply of potable water and water standards, equipment selection, storage, pest control, packaging, transportation, personal hygiene, etc. It also includes training, maintenance of records, quality control, inspection and testing, verification, etc. It means it covers all aspects of food processing operation and management.

For example, GMP says that the food plant establishment should be located away from environmentally polluted areas and industrial activities, which pose a threat of contaminating food; areas subject to flooding unless sufficient safeguards are provided; areas where wastes can not be removed effectively; and areas prone to infestation of pests. GMP requires that the equipment should be located and installed in a manner that permits adequate maintenance and cleaning, functions in accordance with its intended use, facilitates good hygiene practices including monitoring. The equipment should be installed at a distance from the floor and walls to allow proper cleaning and avoid dirt accumulation (recommended minimum 30 cm from floor and minimum 60 cm from walls and other equipment). GMP requires that the conveyors in dry product area should be covered. Guidelines for plant layout, upkeep of operational area, electrical wiring, ergonomic considerations in arranging the work space and almost all the aspects that we have studied in this unit and previous unit come under the purview of GMP. Personal hygiene is a very important component of good manufacturing practice.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you call the quantity of purchase, which optimise total cost in inventory management?

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2. What are the different costs involved in the analysis of inventory?

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3. What are the main reasons for downtime?

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4. Name some records that are maintained for equipment/machinery management?

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5. Expand the following abbreviations?

FPO – ………………………………………………………………………

ISO – ………………………………………………………………………

GHP – …..……………………………………………………………………..

GMP – ………………………………………………………………………

14.14 LET US SUM UP

In this unit we have discussed about the different guidelines for selection of equipment for a fruit and vegetable processing plant, and other commissioning features as movement and installation of equipment, electrical wiring. We also studied the ergonomic considerations for selection and installation of equipment for improvement in workers' performance. The different aspects of maintenance and inspection of equipment and inventory of spare parts are also covered which are very important for reduction of downtime. We also studied about the maintenance of different records, which are helpful in analysis of performance of specific equipment and make replacement decisions. Brief discussions on the certification aspects and Good Manufacturing Practice for a plant are also made at the end of the unit.

14.15 KEY WORDS

Ergonomics : The scientific discipline concerned with understanding the interactions among humans and other elements in a system, and the profession that applies theory, principles, data and methods to design, in order to optimise human well being and overall system performance.

Inventory : It is a stock of materials used to facilitate production or to satisfy customers

EOQ : It is the quantity, which optimises total cost in inventory management.

Downtime : It is the time when the plant or any specific equipment is down or not performing.

14.16 SELF TEST FOR THE COMPLETE UNIT/ ASSIGNMENT

1. Explain the different steps for upkeep of operational area and reduction of downtime?

2. Write short notes on (a) Ergonomics in a food plant design, (b) Inventory management, (c) Selection of equipment.

14.17 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. The initial investment for a standard equipment is lower and duplication of equipment is easier. The repair and maintenance are easier as standard spares are easily available. Standard equipment usually come under some guarantee and are usually the result of many modifications of its original design.

2. The ergonomical factors include body posture and movement, environmental factors (noise, vibration, illumination, climate, chemical substances), information and operation, and the work organisation.

Check Your Progress Exercise 2

1. Proper inspection and maintenance reduce the total downtime, ensure operational readiness, improve job satisfaction and improve safety of workers. Proper inspection helps detect the extent of deterioration of any equipment/machine or their parts, which helps repair/replacement before an actual breakdown occurs.

2. A maintenance schedule is the sequential arrangement by which maintenance is done.

Check Your Progress Exercise 3

1. Economic Order Quantity.

2. The different costs involved in the analysis are the item cost, ordering or setup cost, carrying or holding cost, and stock-out cost.

3. Zmain reasons for downtime are breakdown of a machine, failure in power supply or load shedding, non-availability of suitable raw material, and improper planning, scheduling or machine loading.

4. Facility register, Equipment record card or Plant record card, History Record Card or Log card and Defect analysis record.

5. Fruit Products Order
   International Organization for Standardization
   Good Hygiene Practice
   Good Manufacturing Practice

14.18 SOME USEFUL BOOKS

1. Dul, J. and Weerdmeester (2001). Ergonomics for Beginners 2nd Edition. Taylor and Francis, London.

2. Gopalkrishnan, P. and Banerji, A.K. (1997). Maintenance and Spare Parts management. 2nd Edition, PHI, New Delhi.

3. Gupta, J.B. (198)1. A Course in Electrical Technology. Vol.1, 7th Edition, B.D. Kataria & Sons, Ludhiana.

4. Lal, G., Siddappa, G.S. and Tondon, G.L. (1986). Preservation of Fruits and Vegetables. ICAR, New Delhi.

5. Vilbrandt, F.C., Dryden, C.E. (1959). Chemical Engineering Plant Design. 4th Edition, McGraw Hill, Tokyo. pp.1-188.

UNIT 15 PLANT SANITATION AND EFFLUENT TREATMENT

Structure

15.0 OBJECTIVES

After studying this unit, you should be able to:

- know the importance of plant sanitation for a fruits and vegetables processing industry;
- know the properties of process water and different methods for treatment of process water as well as waste water;
- familiarise yourself with the methods for waste solids upgrading and methods to reduce the discharge volume from a fruits and vegetables processing plant; and
- acquaint yourself with the regulations relating to plant sanitation and waste disposal.

15.1 INTRODUCTION

Plant sanitation plays an important role in the overall work performance of any industry. In particular, in a fruit and vegetable processing industry as we are concerned with handling of food, plant sanitation plays a very vital role. It directly affects food safety. If the food produced by an industry is not safe, then the unit will ultimately loose customers, and may have to shut down. In this unit, we will discuss the various aspects of food processing plant sanitation and see how it affects food safety. Water is one of the major inputs in any fruit and vegetable processing plant as it is needed for a variety of operations such as cleaning, blanching, preparation of syrup or brine, as heat exchange medium or boiler feed, and many other uses. It also directly affects food safety and food plant sanitation. So we will discuss about the requirements of process water and its properties. Another important aspect for any type of industry is waste disposal, as it not only affects food safety, but also affects the surroundings and work environment. Hence, we will discuss about the waste disposal methods. Still more important are the methods that can be taken to reduce the discharge volumes and upgrade the waste solids for further uses, which are not only important for reducing environmental pollution, but also for the economy of operation in a plant. In addition, we will also discuss briefly about the waste and effluent disposal regulations.

15.2 IMPORTANCE OF PLANT SANITATION WITH RESPECT TO FOOD SAFETY, RISKS AND HAZARDS

The word “sanitation” derived from latin word ‘*Sanus*’ means sound and healthy or clean and whole. Thus plant sanitation includes all possible activities to maintain a healthy environment.

Will you consume a food, which is very attractive in colour and aroma, but has a chance of some toxic or otherwise harmful material in it. Of course your answer will be ‘No’; it means that the food plant sanitation principles are mandatory in the production of foods primarily for gaining public acceptance of the products. The processed food obtained from an industry should not only be attractive and nutritious, but also be wholesome and bacteriologically safe. The processed food, even though processed for killing pathogenic organism, is at a greater risk of contamination because it is prepared in large quantities and is handled by many people. Hence, along with proper control on the qualities of raw materials used in processing, proper hygiene at all the work places is very important for obtaining safe food. Since food sanitation has a direct effect on the health of individuals patronising the specific food processing industry, the management needs to lay down definite guidelines for implementation and maintenance of hygienic conditions. This is required even for the survival of the industry itself.

We must realise that sanitation affects every phase of food handling such as purchasing and receiving raw material, transportation and processing operations; and quality control should be maintained throughout. The major sources of contamination of food are air, water, plant, soil, food handler, machinery and equipment, sewage and trucks or cans during transport. The contamination can be in the form of visible contamination by insects, rodents, stones or other extraneous materials, or visible and invisible contamination by micro-organisms. The third type is potential chemical contamination. It means, if slight negligence is observed at any point that would directly bear a risk of food contamination. We should also bear in mind that all the above sources of contamination are directly related with many decisions as selection of a proper site, layout and orientation, ventilation, illumination, water supply and disposal of wastes.

Sanitation is every person's job in a food plant. It should be a part of everyday's policy of the food firm, as ultimately a good sanitation gives us a product free of risks and hazards. If properly practised, sanitation removes the concern about the spreading of communicable diseases or potential food poisoning. Further properly maintained sanitation gives us a product free of contamination and eliminates waste and spoilage. A food prepared under hygienic conditions commands respect in the market. From a legal obligation stand point also, it is important. If the food is prepared, packed, or held under unsanitary conditions, whereby it may become contaminated with filth, it invites legal action.

Sanitation is a responsibility that every person handling or working with food must constantly fulfill. The value of a planned sanitation programme utilising good manufacturing practice includes the following.

- A better product to meet the competition's demands and consumer's expectations.
- A more efficient food plant operation.
- Greater employee productivity.
- Fewer food plant employee accidents.
- Fewer consumer complaints.

Thus food plant sanitation is of prime importance, and several requirements such as adequate supply of potable water, proper sewage disposal facilities have to be fulfilled for maintaining sanitation. However, whatever may be the expense of maintaining a quality sanitation system, there is no point of compromise, as we are going to handle food and ultimately the health and life of the people.

15.3 PROPERTIES AND REQUIREMENTS OF PROCESSING WATER

Water is one of the major inputs in a fruit and vegetable processing plant. It is used in the preparation of brine or syrup, in blanching, in cleaning and washing of fruits and vegetables, different equipment and containers. The other important applications include its use as boiler feed and as heat exchange medium. More than 10,000 litres of water are required to process a tonne of fruits or vegetables.

The processing water must meet the health standards for potable (drinking) water and should be low in mineral salts (calcium, magnesium, sulphur and iron). Potable water is one, which is safe to drink, pleasant to taste and usable for domestic purposes. The water for food processing plants should also be chemically pure to prevent turbidity, off-colour, and off-flavour. The tap water may not be sufficiently pure for use in food products.

15.3.1 Water Hardness

Hardness of water is one of the major properties of water as regards to food processing industry. We all know that if water forms a lather with soap which lasts for at least five minutes, it is called **soft water**. If lather is not formed easily then it is termed as **hard water**. The compounds of calcium and magnesium ions dissolved in water mainly cause the hardness. These ions form precipitates with bicarbonates, sulphates or chlorides present in water instead of forming lather, which is known as hardness.

Hardness of water is further classified as **carbonate hardness** and **non-carbonate hardness**. The carbonate hardness is due to the presence of calcium and magnesium bicarbonate. This type of water is found in chalk and lime stone regions. Non-carbonate hardness is due to the presence of calcium and magnesium sulphates, chlorides, and nitrates. The water in areas having rocks containing these salts is of this type. The carbonate and non-carbonate hardness are also referred to as **temporary hardness** and **permanent hardness,** respectively.

Hardness of water is expressed in terms of milli-equivalents per litre (mEq/l). One mEq/l of hardness producing ion is equal to 50 mg calcium carbonate (50 ppm) in one litre of water.

Table 15.1: Types of hardness

Sl. No.	Degree of hardness	Amount of dissolved compounds	
		mEq/l	mg/l
1.	Soft water	Less than 1	Less than 50
2.	Moderately hard	1-3	50-150
3.	Hard	3-6	150-300
4.	Very hard	More than 6	Over 300

Disadvantages of hard water in processing industry

As hard water fails to give lather with soap, it creates a problem in cleaning operations.

Hardness causes scale on equipment, which acts as an insulating layer against efficient heat transfer and may eventually clog pipes and foul valves. When hard water is used as boiler feed, the growing layer of scale not only reduces boiler efficiency, but also tends to contaminate steam generated in the boilers. Such steam can become alkaline and corrosive to aluminium and tin cans. There is also danger of overheating of the boilers.

The life of pipes and fixtures is reduced as they may rust.

These deposits can harbour bacteria and add to the difficulty of equipment cleanup and may affect food products directly.

Calcium ions have firming effect on certain fruits and vegetables, which may be used to advantage under controlled conditions. But in excessive amounts, the calcium from hard water can cause various textural defects.

Advantages of hard water

As mentioned before, calcium ions have firming effect on certain fruits and vegetables.

The dissolved calcium salts in hard water increases the dietary intake of calcium.

Hard water is more suitable in brewing industries, as it produces better beer.

Methods of removing hardness in water

There are various ways to soften water, depending primarily on the nature of hardness.

Boiling: If water is boiled, temporary hardness only is removed. The bicarbonates are broken down into carbonates, water and carbon dioxide.

$$Ca(HCO_3)_2 \rightarrow CaCO_3\downarrow + H_2O + CO_2$$

The equation of magnesium bicarbonate is similar. The carbonates are precipitated and therefore have no action on soap, being out of solution.

Addition of slaked lime (Clark's process): Slaked lime also removes temporary hardness only. The lime must be added in calculated quantities so that it just neutralises the bicarbonate. Insoluble calcium carbonate is formed.

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2\ CaCO_3\downarrow + 2\ H_2O$$

Addition of washing soda: The method removes both temporary and permanent hardness. Washing soda (sodium carbonate) reacts with the calcium and magnesium salts in hard water forming soluble sodium salts and insoluble calcium and magnesium salts, which remain as a precipitate. The equations are as follows:

For temporary hardness: $Ca(HCO_3)_2 + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2\ NaHCO_3$

For permanent hardness: $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$

Ion exchange process: This method is used in domestic and industrial installations for removing both types of hardness. It involves the use of natural and synthetic resins such as '***permutit***' and '***zeolite***'. The hard water is passed through a column packed with resin and the calcium and magnesium ions in the water are exchanged for sodium ions in the resin. The resin is regenerated from time to time by flushing the column with a concentrated salt (sodium chloride) solution. This replenishes the sodium ions.

Use of sequestering agents: A sequestering agent such as '***Calgon***' (sodium hexametaphosphate), when added to hard water, encloses the calcium and magnesium ions in stable complexes, which are soluble but do not react with soap. *Calgon* is used extensively for domestic purposes, but has limited industrial use, as it is quite expensive.

15.3.2 Other Impurities

The water may have natural pollutants like suspended impurities (clay, silt, sand and mud), dissolved gases like carbon dioxide and ammonia, dissolved minerals like calcium and magnesium salts, lead and microscopic plants or animals. The artificial pollutants include sewage that contains decomposable organic matter and pathogenic agents, industrial wastes, agricultural pollutants, pesticides, fertilizers and physical pollutants such as radioactive substances. Occasionally, the well waters and municipal waters entering a plant will be contaminated with moderate numbers of proteolytic and lipolytic food spoilage organisms. Thus the water to be used for processing needs a critical analysis and remedial steps as required. The municipal water may have a pH as low as 5 or as high as 8.5. Higher pH corresponds to hard water. In-plant water softening or direct neutralisation rectifies it. Pure water has a pH of 7.

We know that chlorine disinfects water; but shall we like to consume water having a sharp chlorine smell? It implies, even though the water is safe from health point of view, still it may not be acceptable to food processing industries. A sharp detectable taste or odour of chlorine may be due to over-chlorination or due to the presence of traces of phenol in the water. Phenol reacts with chlorine to give a strong medicinal odour. Such type of odour can be removed by filtration of water through a bed of carbon or adsorbent clay. Materials such as hydrogen sulphide or organic impurities, if present in water, react with chlorine and inactivate it before chlorine can exert its germicidal effect. Therefore, the amount of chlorine required to disinfect water is dependent on other substances present in the water.

Decomposition of organic matter in water by non-pathogenic bacteria may produce off-flavours and off-odours. When water contains sulphates and reducing types of bacteria, production of sulphite odours may occur. These types of odours can be removed by filtering water through carbon. But prevention of formation of off-odour needs pipeline sanitation to destroy microorganisms.

Dissolved salts in water may impart some colour to the water. Iron salts, if present in water, can be oxidised to ferric hydroxide, which is red-brown in colour. Manganese hydroxides are gray-black in colour. The ion-exchange treatment removes the dissolved mineral impurities. Activated carbon or clay is used to adsorb the colouring pigments. Treatment with alum (aluminium and potassium sulphates) causes flocculation of suspended materials, which are then removed by filtration and centrifugation.

If the supplied water is not suitable for direct food processing applications due to one or more of the above reasons, they can still be used for other uses as heating canned food in a retort, in pre-chilling operations or as a heat exchange medium in evaporator. After the process water has been used, it can be recycled for cleaning of the processing plant and conveying of fruits and vegetables. However, if this recycled water poses threat to the overall sanitation and safety of food, then it is further purified or discarded depending upon the situation.

15.3.3 Disinfection of Water

Chlorination of water is done to kill or inhibit the growth of microorganisms. In addition, chlorinated water is used in the plant for disinfecting products and machinery. Effective chlorination must take into account the chlorine demand of water before a germicidal effect can be achieved. The **chlorine demand** is equal to the amount of chlorine added minus the amount of residual chlorine remaining at the end of 60 minutes of contact at a given temperature and pH. Therefore, it is the amount of chlorine required to destroy bacteria and oxidise organic matter. The break point is when the chlorine demand of water is met, after which further addition results in the formation of free residual chlorine.

For drinking purposes, the residual chlorine level should be less than 0.4 ppm. For cleaning of working equipment and conveyors water containing about 5 ppm of residual chlorine is used. Water to be used in general food plant cleanup may require a residual chlorine level as high as 25 ppm. This is because much of this chlorine will be used up in satisfying the chlorine demand of soil before it can have disinfecting properties. Chlorine is available in cylinders in the form of gas, which are discharged into the water. It may also be derived from hypochlorite preparations.

Ozone eliminates undesirable odour and taste, has a strong viricidal effect and is a powerful oxidising agent. The advantage is that it has no residual effect. **UV rays** are very effective against most viruses and microorganisms. However, the treatment is very expensive, and colour and turbidity of water reduces its effectiveness.

15.3.4 Water for Canning Industry

Chlorinated water should be used in a cannery to maintain hygienic conditions. As far as possible soft water should be used. The hardness of water, especially the temporary hardness, should be low for obtaining clear syrups (sugar solutions). The degree of hardness is still of greater importance in canning of vegetables, as the presence of lime in the blanching water or brine causes toughening of the skins of products such as peas and beans. The addition of sodium hexametaphosphate or sodium phosphate in desirable quantity overcomes the problems.

15.4 PROPERTIES OF WASTE WATER

The composition and contamination loads of the waste water obtained from a fruit and vegetable processing plant varies greatly as it may contain a wide variety of materials (e.g. pulp and peels, soil, detergents, etc.). The treatment of waste water is necessary for converting it into an acceptable final effluent and also to dispose off the solids removed in the process. The nature of the impurities and extent of pollution decide the suitable treatment methods and the degree of treatment, which will ultimately decide the design of the treatment plant.

15.4.1 Nature of Impurities in Waste Water

The wastewaters can be conveniently categorised according to their physical, chemical and biological natures of impurities.

The **physical characteristics** include appearance and odour. The materials in waste water from a fruit and vegetable processing plant are in solution and suspension, which are mostly organic with some inorganic matters. Water in-soluble liquids such as oils and certain solvents may also be present. The materials which remain as particles in the waste water must be removed before sending it to treatment plants or dumping, and should be treated separately. These materials, if discharged into streams and lakes, cause pollution and impart unaesthetic appearance. After removal of gross particulates, the wastewater may contain colloidal and dissolved impurities beyond the specified upper limit for discharge into streams or acceptable to sewage treatment plants. Therefore, further treatments depending upon the impurities are often required.

Under **chemical classification** of impurities, the colloidal and dissolved impurities in waste waters are divided into organic and inorganic materials. The peels, pulps, etc., which form a major part of the waste, are organic in nature. The ratio of nitrogenous constituents to carbohydrate materials present in the organic materials are very important from sewage treatment point of view. The nitrogen rich wastes accelerate the decomposition process by helping growth and activity of the sewage microorganisms, and hence sewage treatment plants are designed to receive wastes rich in nitrogen. Many vegetable wastes have higher nitrogen:carbohydrate ratio. As the fruit wastes have a high carbohydrate-low nitrogen content, they need supplementation with nitrogenous material before treatment in a sewage plant.

Very high and low pH waste water require neutralisation to bring down the pH to about 6-9 before discharging as it may kill aquatic life and essential microorganisms in sewage treatment plants or natural waters. The synthetic detergents and surface-active materials cause operating problems in sewage treatment plants, which can be easily avoided by using biodegradable detergents. If there is any bad odour from the wastewater, it needs an additional treatment.

The **biological nature** of impurities is very important. As previously discussed, the food plant wastes are generally organic, which are biodegradable. Mostly aerobic organisms are responsible for the degradation. In this process, carbohydrates are transformed into carbon dioxide and water, and nitrogen residues are converted to nitrates. Intermediate products such as alcohols, acids, amines, and ammonia are also produced during the process if the oxidation/ decomposition is incomplete. These intermediates often impart bad odour, and may be toxic to plant and fish life. These intermediates will undergo further degradation in nature.

15.4.2 Biological Oxygen Demand

Oxygen is required in the process of decomposition of organic waste by microorganisms. The amount of oxygen required is directly proportional to the amount of organic pollutants. This amount of oxygen, which is consumed for oxidation of organic contaminants is termed the biological oxygen demand (BOD).

BOD is an important measure of the dissolved organic wastes in water, and is of essential importance for the improvement of sewage and water. The BOD test measures the quantity of oxygen in ppm (parts per million) required by aerobic microorganisms to stabilise waste or polluted water under specific conditions (generally 20°C for 5 days). For example, the BOD of tomato processing wastes and citrus processing wastes vary between 80-4000 and 1000-5000 ppm. The BOD of milk processing waste water varies between 20-650 ppm only. When the BOD of waste discharged into a stream is excessive, there is fast depletion of the stream’s oxygen, which disturbs stream’s ecology, kills aquatic wild life and destroys beneficial microorganisms. The higher the BOD values, costlier will be the treatment before it is discharged into municipal wastes.

Sewage and waste treatment plants can be rated in terms of their BOD-removing capacity. The result of the BOD test determines whether a simple primary sewage treatment plant is sufficient or a complete treatment plant is required. The classification of streams by regulatory agencies is also often based upon BOD standards. Antipollution regulations are written to include maximum permissible BOD loadings into natural waters.

15.4.3 Chemical Oxygen Demand

The chemical oxygen demand (COD) is another useful test, which measures chemically oxidisable material in a liquid sample. This test is based upon the fact that all organic compounds, with a few exceptions can be oxidised quantitatively by strong oxidising agents, such as potassium dichromate, potassium permanganate, etc. under acid conditions. Thus it also measures chemically oxidisable inorganic materials.

15.4.4 Other Chemicals

The food plant wastes may sometimes be contaminated with highly toxic materials such as pesticides and disinfectants. Such toxic substances may kill the plant's normal microbial flora essential to sewage and waste treatment. Under such cases, it is advisable store it separately before discharging it into a convenient location or to dilute the wastes substantially and then send it to the treatment plant in very small quantities at a time.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the disadvantages of hard water for a food processing industry?

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2. Name the different methods for removal of hardness of water?

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3. What are the major disinfecting agents of water?

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4. What will happen if a high BOD waste water is discharged into a sewage treatment plant?

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15.5 WASTE WATER TREATMENT

The extent to which the pollution load must be decreased before waste water leaves a food processing plant is highly variable. It depends on many factors such as whether the waste water will be discharged to a municipal sewage or commercial waste treatment plant, and if so what is the maximum pollution load this plant can treat; what will be the cost for such treatment and can it be done more economically by the food plant itself; what dumping privileges does the food plant have and what pollution laws apply, and so on. The waste water treatments may be classified under the following headings.

15.5.1 Primary Treatments

The primary treatments include screening, filtration, centrifugation and settling or sedimentation. Large solid matters and heavy sediments are removed by screening through vibrating sieves. This is essential to protect and safeguard the subsequent treatment units. Smaller particles may be removed by filtering or centrifuging. Mostly the slow sand or biological filters and rapid sand or mechanical filters are used for the purpose.

Suspended impurities are allowed to settle or rise in large sedimentation tanks and removed. The rate of sedimentation can be enhanced by the use of alum or ammonium sulphite, which produces a sticky flocculant precipitate. Scum or oil is readily skimmed from such tanks, and settled solids are concentrated. These primary treatments may remove some 40% of the wastewater's BOD and about 75% of total solids, depending on the nature of the waste.

15.5.2 Secondary Treatments

The primarily treated sewage in small food processing industries is discharged into municipal treatment plants. But in large plants, some additional treatments similar to those carried out in municipal sewage installations are carried out after the primary treatments. The basic purpose of these treatments is to reduce the BOD level of the wastes. These secondary treatments commonly involve the use of trickling filters, activated sludge tanks, and ponds of various types. Sometimes these are preceded by use of anaerobic digesters.

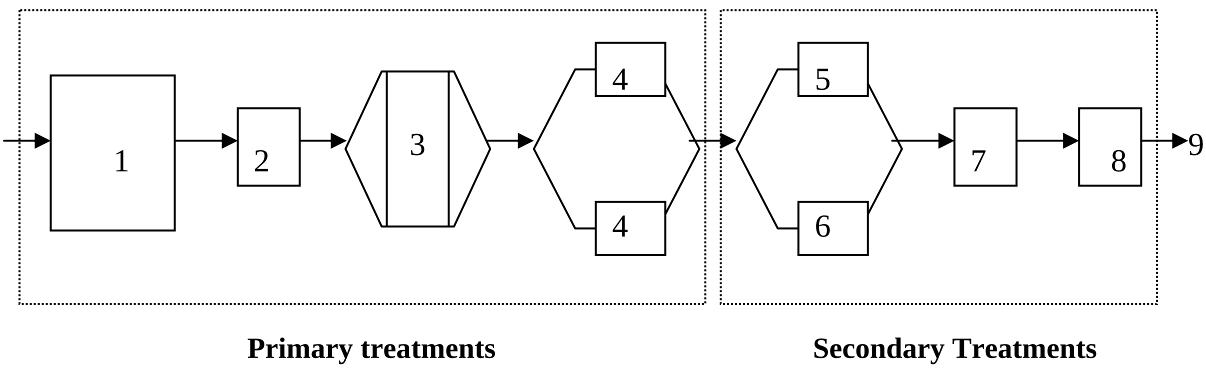


Figure 15.1: Waste water treatments: 1) Screen, 2) Shredder, 3) Grit chamber, 4) Primary sedimentation tank, 5) Trickling filter, 6) Activated sludge tank, 7) Secondary sedimentation tank, 8) Chlorination tank, and 9) final effluent.

15.5.3 Tertiary Treatments

The tertiary treatments or final treatments or advanced treatments applied to potable water for special food processing uses include water softening, ion exchange and carbon filtration. These treatments are also referred to as "polishing treatments". These are generally not needed or used to treat food plant wastewaters.

When a food plant has no means for disposing of treated waste waters, it may choose to discharge these waters into sewer lines for further handling by a municipal plant. The municipal plants usually chlorinate the waste waters before disposal into waterways or irrigation channels.

15.6 WASTE SOLIDS UPGRADING AND TREATMENT

You must have observed how a significant portion of the raw material is wasted during household processing of fruits and vegetables or cooking. Can you guess how much would be the amount of waste materials from a 10 tonne per day capacity fruit processing plant. If these wastes are not utilised properly, it affects the economic success of the industry. These wastes include crown, peel, core, seeds, pomace, trimmings, shells, stalks, etc. Table 15.2 gives an idea of the extent of waste during processing for different fruits and vegetables.

Table 15.2: Extent of wastes during processing for selected fruits and vegetables

Items	Waste as percent original raw material	Items	Waste as percent original raw material
Apples	30-35	Grapes	20-30
Mango	25-35	Peas	20-25
Guava	40-45	Beans	15-20
Pineapple	45-50	Carrots	5-7
Lemon	40-45	Tomato	8-10
Orange	50-55	Misc. vegetables	20-25

Most of the above wastes obtained from a fruit and vegetable processing industry are generally mixed with water. By suitable upgrading and treatment, they can be of several beneficial uses, as mentioned below.

- The by-products can be recovered from the waste water and spread out thinly on agricultural land for grazing of cattle. The unused material may be disposed off by burning.
- If the waste food are collected separately taking care that it does not mix with other refuse like broken glass, polythene pieces etc., they can be boiled, shredded, dried and enriched with minerals and can be used as poultry feed.
- Under favourable economic conditions most wastes can be processed or altered to a more useful and valuable material. Table 15.3 gives some beneficial uses of fruits and vegetables processing by-products. In fact, you will soon discover that no part is a waste during the processing of fruits and vegetables.
- Fruit and vegetable skins, pulp, and pits can be pressed to further remove water and be converted into compost for improving soils. Some wastes are ground into the plough as fill. Vermicomposting is one novel way for getting bio-fertiliser from bio-degradable wastes with the activities of earthworms.
- Sludge and residues remaining after waste water and sewage treatment have been dried and sold as fertilizer or used wet for this purpose. Sometimes they are incinerated, leaving only a small amount of ash, which can be disposed conveniently.
- Fruit and vegetable wastes are also used as a source of fermentable carbohydrate.
- All kinds of glass, solids, polythene, paper and metal can be recycled. Each of these materials should be collected separately for recycling.
- When none of these uses are feasible, then waste may be burned as garbage where law permits.

Table 15.3: Beneficial uses of fruits and vegetable wastes

Fruit	Nature of waste	Uses
Mango	peels, stones, pulping waste	starch, fat, pectin, vinegar, syrup, alcoholic beverage
Pineapple	peels, cores, trimmings	vinegar, syrup, citric acid, candied cores
Grapes	stem, seeds, seed hulls	cream of tartar, seed oil, tannin, vinegar, pectins, wines, stock seed
Apple	pomace, Cores cull	Pectin, cider, vinegar, soft drink, jelly base, Ingredient in cattle feed
Citrus	peels, pomace, seeds	pectin, essential oil and seed oil
Peaches, apricots and cherries	piths, kernels	oil, stock feed
Tomato	seeds, peels, and cores	animal feed, fertiliser, resin from peels, oil from seeds for soap making and edible use, peels

15.7 LOWERING DISCHARGE VOLUMES

Even though there are several ways to treat waste water, but you will agree that for minimising costs involved with waste water treatment and reducing the size of treatment plant, it is better to try to lower the discharge volume. The first step in lowering the discharge volume from a food plant is to reduce the amount of water used in the plant, which can be achieved by some modification in processing methods. Other means are recycling of the used water or treated waste water for some other non-priority areas.

15.7.1 Waste Water Treatment

For very large quantities of waste disposal, land treatment is the cheapest and best. The recovery of by-products from the wastes not only offers good economy, but also reduces pollution. However, these practices are viable only for big processing plants.

It is better to separate the solid wastes from the liquid. The coarse particulates and fine solids can be separated with different types of screens and settling tanks, as discussed in the previous section. The clear and problem free effluent can be drained.

Instead of segregating the different waste streams from a particular plant, the concentrated and high BOD wastes need to be handled separately. Thus large volumes of dilute waste water can be saved from high contamination. Some pre-processing ingredients are available which can reduce waste loads needing treatment.

15.7.2 Recycling and Modified Processing Methods

There are many modified processing operations, which can give lesser volumes of waste water as compared to conventional processing methods.

Reuse of water for less demanding operations is the most suitable one. The water obtained from heat exchangers or the boiler feed can be used for cleaning and conveying of fruits and vegetables. This decreases waste load to a considerable extent.

Recovery of salt by evaporation of the brine and crystallisation is possible. In addition to a potential saving in salt costs, it also avoids pollution that might have been caused due to discharge of the brine. However, the crystallised salt slurry may contain some organic matter, which has to be separated before the salt can be reused. This is done by incineration of the slurry, which leaves a trace of carbon. The salt can be reused after certain modifications such as adjusting the pH, and filtering to remove the carbon. Such processes, however, must also be considered in terms of benefit-cost ratio.

Loosening the skins of fruits and vegetables for peeling is usually done in dilute caustic solution. This method consumes a lot of water, which is ultimately wasted after peeling. Instead, we can achieve a considerable saving in water by peeling using concentrated sodium hydroxide (NaOH) solution combined with vigorous mechanical action. The BOD of the wastewater per weight of raw material obtained by this 'dry caustic method' is only about one-third that generated by the dilute caustic solution.

Similarly, steam blanching of vegetables saves considerable water from being polluted as compared to conventional hot water blanching. Further, as less amount of solids are dissolved in the blanching medium, the effluent has low BOD level. It is also reported to give better texture of the vegetables after freezing, thawing, and cooking as compared to the hot water blanching method.

Check Your Progress Exercise 2

Note: a) Compare your answers with those given at the end of the unit.

1. State True / False:

   a) The primary treatment of wastewater involves the use of activated sludge tanks.

   b) The secondary treatments of wastewater are also known as "Polishing treatment".

   c) In small food processing plants the secondary treatment of wastewater is not carried out.

   d) The amount of wastes from mango fruits is in the range of 5-10 percent of the raw material.

   e) Recycling of water in food processing plant reduces considerable wastewater.

15.8 PLANT SANITATION AND EFFLUENT TREATMENT AS A CONTINUOUS RESPONSIBILITY

The ever increasing population, increase in number of industries and vehicles, migration of the people from rural areas to cities and towns, and several other factors have added to the amount of wastes. Now there is more concentration of people in areas of processing than the areas of production. This has added to a growing problem of waste disposal, which has always meant expense to food processors. In particular, in fruit and vegetable processing industry huge amount of waste and effluents are released. Most often the wastes are more than the preserved edible materials. It must be disposed off regularly and efficiently to prevent contamination of any food product. In addition, it is very important to prevent pollution of atmosphere and water supplies by proper disposal of the waste and effluents from such plants.

The wastes obtained from a fruit and vegetable processing plant are mostly organic and biodegradable. Large quantities of inorganic impurities from fruit / vegetable washing process may also be obtained. Small doses of pesticide residues, nitrates and nitrites formed out of residual protein and ammonical compounds during processing may also occur. All of these, if disposed as such to the surrounding, will pollute the surface and ground waters used for drinking purposes. This will ultimately add to the ever-growing problems of the human being. Therefore, every necessary step should be taken for effluent treatment of a food processing plant to protect the environment. All of these are moral obligations also.

The major source of air pollution in a fruit and vegetable processing industry is fuel burning in boiler for steam raising and heating which mainly emits smoke/ particles/dust, sulphur oxides and oxides of nitrogen. The intensity of emission varies with the type of fuel and boiler used, and the boiler-firing practice adopted. Minor discharge of benzpyrenes and trace metals contained in coal may also be present. Provision of inadequate smoke stack (lower height) and / or existence of unfavourable meteorological conditions may result in increased ground level concentration of pollutions which can result in discomfort and respiratory complaints initially and impairment of lung functions in the long run.

Therefore, it is our responsibility to take a holistic approach of production and processing as well as for the minimisation of wastes disposed from a food plant. Besides, if a food plant pollutes the surrounding atmosphere, it ultimately earns bad reputation and looses customers.

15.9 WASTE / EFFLUENT DISPOSAL REGULATIONS

Setting of the project has a very important role to play in the control of pollution. While deciding the location of the project, the weightage has to be given to the availability of power and water. It is also necessary to know in advance whether no objection certificate from the pollution control angle would be admissible for the proposed industry.

There are several pollution control acts to protect and improve the natural environment including forests, lakes, rivers and wild life and have compassion for leaving creatures. The Pollution Control Law Series: PCLS/02/1992 has the details of these regulations. It also contains standards notified with respect to the important pollutants as well as rules governing hazardous wastes, hazardous chemicals, etc. notified under Environment (Protection) Act, 1986. The Environment Ministry / Department and the State Pollution Control Boards are responsible for giving clearance on these aspects to any industry.

The Act specifies the wastewater discharge standards for any food and fruit processing industry, as given in Table 15.4. Table 15.5 gives the specified emission levels from boilers as covered under the Act.

Table 15.4: Wastewater discharge standards for food and fruit processing industry

Category	Concentration not to exceed				Quantum
	pH	Suspended solids (mg/l)	Oil and grease (mg/l)	BOD at 27°C for 3 days (mg/l)	g/tonne of product
a) Above 0.4 tonnes/day	6.5-8.5	50	10	30	-
b) 0.1-0.4 tonne/day	6.5-8.5	-	-	300	-

Table 15.5: Limits of emission from boiler houses

Capacity of Boilers	Particulate matters emission (mg/Nm³)
Less than 2 ton/h	1200*
2 to less than 10 ton/h	800*
10 to less than 15 tons/h	600*
15 tons/hr and above	150**

(* To meet the respective standards, cyclone / multicycle is recommended as control equipment with the boiler. ** Bag filter/ESP is recommended as control equipment. In the above table, 12% of carbon dioxide correction shall be the reference value for particulate matter emission standards for all categories of boilers.)

There are several other schedules in the Pollution Control Act dealing with discharge of effluents, ambient air quality standards, standards for control of noise pollution, etc. The Bureau of Indian Standards (BIS) has also specified regulations for manner, condition and fees for grant and renewal license for environmental management system.

The Factory Act, 1948 has several clauses relating to health measures and waste disposal aspects in any type of factory. Under the Act, the occupier is required to keep the factory premises clean and free from waste and effluvia. He shall make arrangements for sweeping and removing dirt and refuse daily, cleaning with disinfectant, painting the walls, doors and windows at specified time intervals. Effective arrangement shall be made for treatment of wastes and effluents due to the manufacturing process carried on therein, so as to render them innocuous and for their disposal.
If any process or machine gives off dust/fumes or other impurity which are likely to be injurious or offensive to the workers, effective measures should be taken to prevent its inhalation and accumulation in any workroom. The exhaust appliance, if used, shall be applied as near as possible to the point of origin of the dust, fume or other impurity. Besides, such points shall be enclosed as far as possible. The factory premises should be adequately ventilated by circulation of fresh air and comfortable temperature should be maintained in every workroom.

15.10 ENVIRONMENT IMPACT

Now-a-days we have become very conscious of the environmental pollution and degradation aspects at all levels. Therefore possible environmental impacts are taken into serious consideration before and after setting up an industry in a particular location. For example, the discharge of solid and liquid wastes, smoke and polluted air will change the physical and chemical characteristics of surrounding environment and water body. Sometimes, it has so happened that due to deposition of solids and/or discharge of harmful chemicals, streams have become unfit for drinking water purpose, or even for bathing. Similarly you must have observed how the surroundings near a thermal power plant or stone crushers are heavily polluted, which affect the normal life of the people. Hence, preparation of environmental management plan is required for formulation, implementation and monitoring of environment protection measures during and after commissioning of the projects.

The environmental impact not only considers the changes in air or water qualities in the area, but it also considers the biological, cultural and socio-economic components of the environment. It is essential to assess these environmental impacts and the tool used for the purpose is known as **Environmental Impact Assessment** (EIA).

In recognition of the role that EIA could play, Ministry of Environment and Forests, has published a list of 29 industries, which are required to obtain environmental clearance from competent authority in addition to a NOC from Pollution Control Board. Even though, the food and fruit processing industry, at present, is not included in the list, still the environmental impact for such industry can not be ignored.

Environmental impact has a very wide scope in the formulation of a project. Even for site selection, the environmental attributes such as topography, geology, water resources (quantity and quality), soil characteristics, land productivity, flora and fauna, socio-economic conditions are considered. The proximity to water resources, raw materials, markets, availability of land and human resources etc. are other project attributes. An environmental management plan is formulated to ensure that the resources are used with maximum efficiency, waste generation is minimised, residuals are treated adequately and products are recovered and recycled to the maximum possible extent.

EIA consists of establishing quantitative values for selected parameters, which indicate the quality of the environment before, during and after the proposed development activity. EIA involves three steps, viz. identification, prediction and evaluation of impacts. First the environmental parameters to be investigated for possible impacts are listed. Then with the help of suitable models real impacts for proposed development are assessed. Though fairly good models are available for prediction with respect to air and water components, predictions of biological, socio-economic and cultural impacts are often subject to uncertainty. The degree of uncertainty could however be ascertained mathematically or indicated in qualitative terms while presenting prediction results. The evaluation step calls for conversion of predicted values for various environmental parameters to a comparable set of units using some system of normalisation. At present many consultancy firms are also doing EIA studies, which can be hired for the purpose.

Check Your Progress Exercise 3

Note: a) Compare your answers with those given at the end of the unit.

1. Fill in the blanks:

   a) The major source of air pollution in a fruits and vegetables processing industry is _________________.

   b) The extended form of EIA is _________________________________.

15.11 LET US SUM UP

In this unit we studied about the importance of plant sanitation for a fruits and vegetables processing plant and we observed that sanitation is very important for the safety of food and overall performance of the industry. We discussed about the different properties of process water and steps for removal of hardness and disinfection of water so as to make it fit to be used as process water. We also discussed about the methods for waste water treatment and water solids upgrading and treatment. The different methods for lowering discharge volumes such as waste water treatment and recycling and modified processing methods are also covered in the unit. Thus we are now familiar with the general sanitation and waste disposal aspects of a fruits and vegetables processing plant.

15.12 KEY WORDS

Carbonate hardness : Hardness due to presence of calcium and magnesium bicarbonates; also known as temporary hardness.

Non-carbonate Hardness : Hardness due to the presence of calcium and magnesium sulphates, chlorides and nitrates; also known as permanent hardness.

Chlorine demand : It is the amount of chlorine required to destroy bacteria and oxidise organic matter.

BOD : The amount of oxygen consumed for oxidation of organic contaminants in water.

15.13 SELF TEST FOR THE COMPLETE UNIT/ ASSIGNMENT

1. Explain the different methods for disinfection of water?
2. Explain the importance of waste solids upgrading and treatment?
3. Explain the requirement of process water?

15.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Hard water creates a problem in cleaning operations. Hardness causes scale on equipment, which reduces heat transfer and contaminates steam produced in boilers. The life of pipes and fixtures is reduced as they may rust. The scales house bacteria and affect food products directly. Calcium present in hard water in excess amounts can cause various textural defects.

2. The methods for removal of hardness of water are boiling, addition of slaked lime, addition of washing soda, ion exchange process, and use of sequestering agents.

3. Chlorine, Ozone, UV rays

4. There will be fast depletion of the stream's oxygen, which disturbs stream's ecology, kills aquatic life, and beneficial micro-organisms for sewage conversion.

Check Your Progress Exercise 2

1. a) False
   b) False
   c) True
   d) False
   e) True

Check Your Progress Exercise 3

1. a) Boiler
   b) Environmental Impact Assessment (EIA)

15.15 SOME USEFUL BOOKS

1. Bhatia, S.C. (2001). Environmental Pollution and Control in Chemical process Industries. Khanna Publication, New Delhi.

2. Central Pollution Control Board (1992). Pollution Control Acts, Rules and Notifications Isued thereunder. Pollution Control Law Series, PCLS/02/1992, CPCB, Delhi.

3. Chatterjee, A.K. (1996). Water supply, Waste Disposal and Environmental Pollution Engineering. 5th Edition. Khanna Publication, New Delhi.

4. Gould, W.A. (1990) CGMP's/Food Plant Sanitation. CTI Publication, Inc., Baltimore.

5. Potter, N.N., Hotchkiss, J.H. (1996). Food Science. 5th Edition. CBS Publishers and Distributors, New Delhi.

6. Roday, S. (1999). Hygiene and Sanitation in Food Industry. 1st Edition. Tata McGraw Hill, New Delhi.

EXPERIMENT 1 PREPARATION OF FRUIT BEVERAGES – SQUASH, CORDIAL, RTS BEVERAGE, FRUIT NECTAR AND SHARBETS

Structure

1.1 INTRODUCTION

Tropical countries, like India, have a vast scope of providing delicious cold drinks during hot summer particularly the fruit beverages. Due to increased consumer awareness with respect of quality, safety and health, these fruit beverages are becoming more and more popular and are gradually acquiring a chunk of the market share of cold drinks.

Fruit beverages are easily digestible, highly refreshing, thirst quenching, appetizing and nutritionally far more superior to the synthetic aerated drinks. Fruit beverages can be classified as fermented and unfermented. In this practical, however, we will only deal with unfermented beverages which do not undergo any alcoholic fermentation.

Objectives

After going through this experiment, you should be able to:

- describe methods of preparation and preservation of unfermented fruit beverages; and
- know the difficulties, precautions to be taken and technical know-how of the final product quality.

1.2 EXPERIMENT

1.2.1 Principle

Fruit beverages are prepared from fruit juices or pulp and preserved by chemical preservatives or by heat application.

1.2.2 Requirements

Raw materials, equipment and apparatus

1. Fruit/vegetable, sugar
2. Peeler
3. Juicer
4. Pulper
5. Filter cloth / sieve
6. Pans of suitable size
7. Heaters
8. Thermometer
9. Crown corking / capping machine
10. Corks / caps
11. Sterilizer/Pasteurizer
12. Volumetric flask
13. Measuring cylinder
14. Weighing balance
15. Potable water

Chemicals and reagents

1. Hydrochloric acid
2. Citric acid / ascorbic acid
3. Potassium metabisulphite
4. Sodium benzoate

1.2.3 Procedure

General method for preparation of fruit juice

The general process for the preparation and preservation of unfermented fruit beverages is as follows:

- Select only fully ripe and quality fruits. Care should be taken not to include either over ripe or under ripe fruits as it affects the final product quality.
- Sort and reject/trim diseased, damaged or decayed fruits. Wash them properly with water or dilute hydrochloric acid (1 part acid: 20 parts water) to remove dirt and spray residues of arsenic, lead, etc.
- Extract juice from fresh fruits by crushing and pressing them by using suitable juice extractors, basket presses or fruit pulpers. Fruits, which require preheating, should be preheated before extraction.
- Strain and filter the juice to remove suspended matter consisting of broken fruit tissue, seed, skin, etc. Clarify the juice if required using a suitable method.
- Fortify the juices with vitamins to enhance their nutritive value, to improve taste, texture or colour and to replace nutrients lost in processing, if required.
- The preservation could be by physical methods (pasteurization, sterilization, etc.) or by chemical preservatives.
- Wash bottles thoroughly with hot water and fill them leaving 1.5-2.5 cm headspace. Seal with crown corks (by a crown corking machine) or with caps (by capping machine).

a) Squash

Squash should contain at least 25% fruit juice or pulp and 40 to 50% total soluble solids commercially. About 1% citric acid and 350 ppm Sulphur dioxide or 600 ppm sodium benzoate are added as preservatives.

Method of preparation

For the preparation of 10 litres of squash follow the procedure given below:

- Calculate the amount of juice required as per commercial specification

  Required juice = (25/100) × 10 = 2.5 lts.

- Measure the TSS using a refractometer (say the TSS is 30%)

  Calculate the total solids content of the juice i.e. 0.3 X 2.5 = 0.75 kg

- The final required TSS content in the product is to be say 50%. The TSS required to be added to obtain the final product is (0.5 × 10 – 0.75) kg = 4.25 kg

- The amount of soluble solids in the form of citric acid and KMS is

  Citric acid @ 1%, in the final produce is 100 g i.e. 0.1 kg.

  600 ppm SO_2 (1.5g/litre of KMS being equivalent to 1000 ppm) @ 0.9g KMS/litre. i.e. 0.9 x 10 = 9 g i.e 0.009 kg.

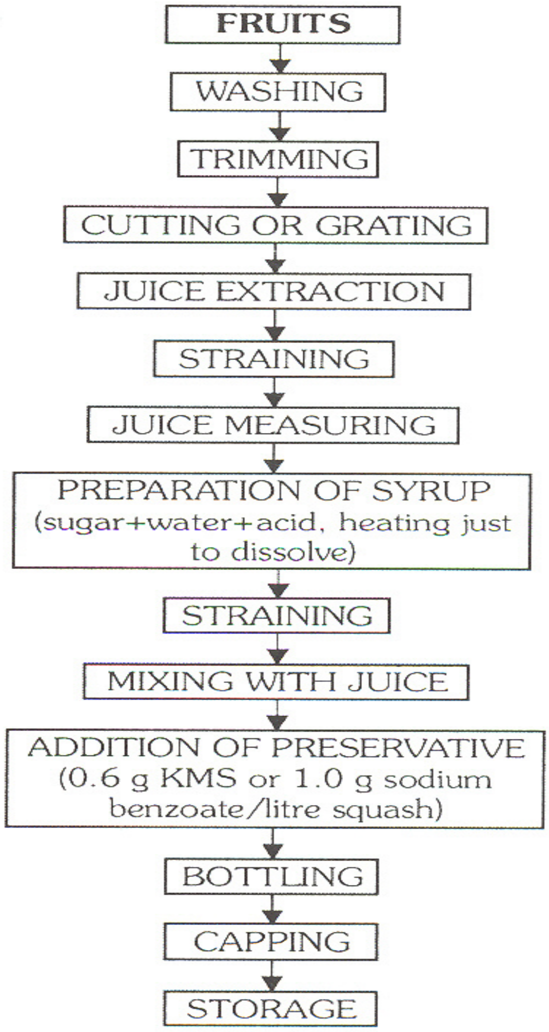
- Amount of solids to be added in the form of sugar is 4.25–(0.1+0.009)= 4.141 kg.

- Ingredients

	Juice	-	2.5 kg	
	Sugar	-	4.141 kg	4.25 Kg
	Citric acid	-	100 g	
	KMS	-	9 g	
	Water	-	(10-2.5+4.25) = 3.25 Lts	

- As prescribe dissolve sugar in water, add citric acid and give a boil, strain through a fine muslin cloth. Cool the syrup completely. Mix the fruit juice with syrup. Add colour as required and then essence. Grind the preservative in a saucer with a spoon. Add little water. Pour into squash. Add more juice and transfer all the preservative to the squash.

Flow sheet



b) RTS Beverage

This is a type of fruit beverage containing at least 10% fruit juice and 10% total soluble solids besides about 0.3% acid. It is not diluted before serving and, hence, is known as ready-to-serve (RTS) beverage.

Method of preparation

For the preparation of 10 lts. of RTS beverage, follow the procedure given below:

- Calculate the amount of juice required as per commercial specification

  Required juice = (10/100) × 10 = 1.0 lts.

- Measure the TSS using a refractometer (say the TSS is 30%)

  Calculate the total solids content of the juice i.e. 0.3 × 1.0 = 0.30 kg

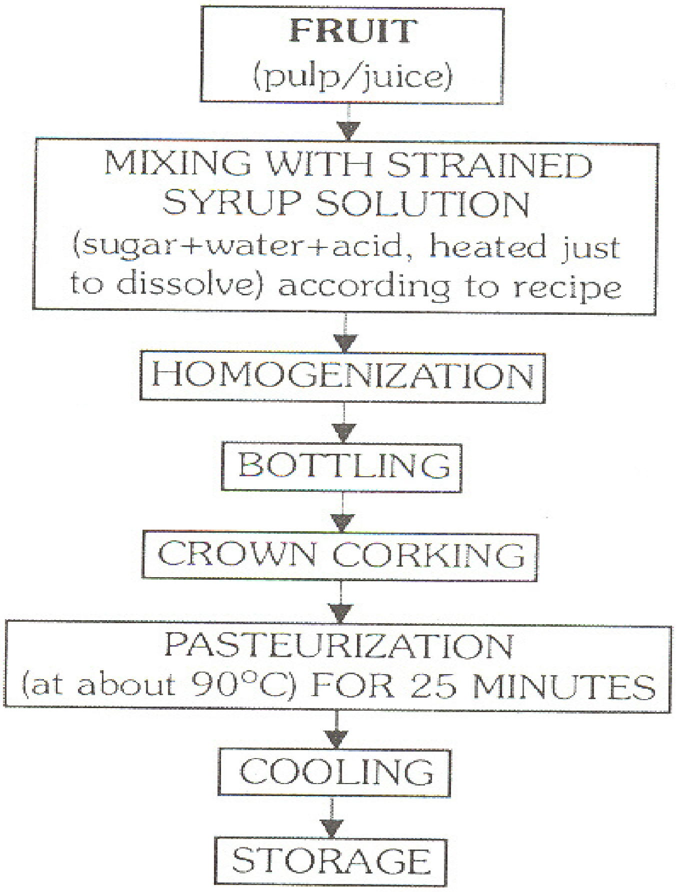
- The final required TSS content in the product is to be say 10%. The TSS required to be added to obtain the final product is (0.1×10–0.30)kg = 0.70 kg

- The amount of soluble solids in the form of citric acid and KMS is

  Citric acid @ 0.3%, in the final produce is 30 g i.e. 0.03 kg.

- Amount of solids to be added in the form of sugar is 0.70–0.03=0.67kg.
- Add calculated amount of sugar to about 2 lts of water and heat it till it dissolves completely. Add citric acid and juice to the sugar syrup and makeup the volume to 10 lts. Mix it well.
- Heat up to 90°C, fill hot in clean pre-sterilized glass bottles up to brim, seal and cool in the air or fill in bottle, seal and heat process (90°C for 25 min.).

Flow sheet



c) Fruit Nectar

This is a type of fruit beverage containing at least 20% fruit juice/pulp and 15% total soluble solids besides about 0.3% acid. It is also not diluted before serving.

Method of preparation

For the preparation of 10 lts. of fruit nectar, follow the procedure given below:

- Calculate the amount of juice required as per commercial specification

  Required juice = (20/100) × 10 = 2.0 lts.

- Measure the TSS using a refractometer (say the TSS is 30%)

  Calculate the total solids content of the juice i.e. 0.3 × 2.0 = 0.60 kg.

- The final required TSS content in the product is to be say 15%. The TSS required to be added to obtain the final product is $(0.15 \times 10 - 0.60)$ kg = 0.90 kg.
- The amount of soluble solids in the form of citric acid and KMS is

  Citric acid @ 0.3%, in the final produce is 30 g i.e. 0.03 kg.

- Amount of solids to be added in the form of sugar is 0.90–0.03=0.87kg.
- Add calculated amount of sugar to about 2 lts of water and heat it till it dissolves completely. Add citric acid and juice to the sugar syrup and makeup the volume to 10 lts. Mix it well.
- Heat the RTSB / Nectar up to 90°C, fill hot in clean pre-sterilized glass bottle up to brim, seal and cool in the air or Fill in bottle, seal and heat process (90°C for 25 min.).

d) Cordial (Lime)

- Extract the juice and strain through a fine muslin cloth to remove all pulp
- Add preservative (KMS) 2 gms per litre of lime juice
- Pour in bottles and keep for 1-2 months. All the sediment settle down and the juice becomes clear
- Pour all clear juice without disturbing the sediment. Use the recipe and proceed as for squash.

Flow sheet

Same as RTS Beverage

e) Sharbet

Sharbet should contain at least 65% total soluble solids, suitably acidified and may or may not contain fruit juice.

Method of preparation

For the preparation of 10 lts. of sharbet follow the procedure given below:

- Take about 6 lts. of water and add approx. 6.5 kg of sugar and dissolve it properly.
- Add the required flavour.
- Make up the volume to 10 lts. and adjust the TSS to 65%.

1.2.4 Observations

Determine TSS and acidity.

Note: The procedure for the calculation of TSS and acidity can be seen in the practical manual of BPVI-007 Course VII ‘Food Quality Testing and Evaluation’ and BPVI-003 Course III ‘Food Chemistry and Physiology’.

1.2.5 Result

Acidity of the given squash, cordial, nectar, RTS beverage = % (w/v)

TSS of the given squash, cordial, nectar, RTS beverage = %

1.3 PRECAUTIONS

- All equipment used in the preparation of fruit juices and beverages should be rust and acid proof.
- Copper and iron vessels should be strictly avoided as these metals react with fruit acids, and cause blackening of the product.
- Avoid exposure of juice to atmosphere as it will spoil the colour, taste and aroma and also reduce the Vitamin content.

EXPERIMENT 2 PRODUCTION OF FRUIT JAM, JELLY, MARMALADE, FRUIT BUTTERS, CONFECTIONARY AND CHEESE, PRESERVE AND CANDIES

Structure

2.1 INTRODUCTION

Jam, jellies and preserves etc., are very common products made out of fruits and vegetables that permit consumers to taste the fruits of their liking even during lean periods or when the fresh produce is expensive. These products also permit the diversification of the fruit use to avoid distress sale during the production season and to minimize the post harvest wastages. These practices of preparing the processed products are simple and could be attempted at household levels even in rural settings if adequate food safety related precautions are put in place. Besides, there are several fruits that are not cultivated in large quantities to permit large scale processing. Still these fruits are novel enough to convert them into the processed products and present them to consumers as niche products.

Objectives

After going through this experiment, you should be able to:

- describe methods of preparation and preservation of jam, jelly and preserve etc.; and
- know the difficulties, precautions to be taken and technical know-how of the final product quality.

2.2 EXPERIMENT

2.2.1 Principle

Jam, Jelly and Preserve are prepared from fruit pieces or pulp and preserved by high sugar concentration/chemical preservative or by heat application.

2.2.2 Requirements

Raw materials, equipment and apparatus

1. Fruit/vegetable, sugar
2. Peeler
3. Pulper
4. Filter cloth / sieve
5. Pans of suitable size
6. Heaters
7. Thermometer
8. Crown corking / capping machine
9. Corks / caps
10. Sterilizer/Pasteurizer
11. Volumetric flask
12. Measuring cylinder
13. Weighing balance
14. Potable water

Chemicals and reagents

1. Hydrochloric acid
2. Citric acid / ascorbic acid
3. Potassium metabisulphite
4. Sodium benzoate

2.2.3 Procedure

a) Jam

- Jam is a product made by boiling fruit pulp with sufficient sugar to a reasonably thick consistency, firm enough to hold the fruit tissues in position. Apple, pear, sapota, apricot, loquat, peach, papaya, karonda, carrot, plum, strawberry, raspberry, mango, tomato, grapes and muskmelon are used for preparation of jams.

- It can be prepared from one kind of fruit or from multiple kinds. Commercial jams such as tutti-frutti can be prepared from pieces of fruit, fruit scraping and pulp adhering to cores of fruits, which are available in plenty in canning factories.

- Jam contains 0.5 - 0.6% acid and invert sugar should not be more than 40%.

Method of preparation

For the preparation of 10 kg of jam follow the procedure given below:

- Calculate the amount of fruit pulp required as per commercial specification

  Required pulp = $(45/100) \times 10 = 4.5$ kg.

- Measure the TSS using a refractometer (say the TSS is 50%)

  Calculate the total solids content of the juice i.e. $0.5 \times 4.5 = 2.25$ kg.

- The final required TSS content in the product is to be say 68%. The TSS required to be added to obtain the final product is $(0.68 \times 10 - 2.25)$ kg = 4.55 kg.

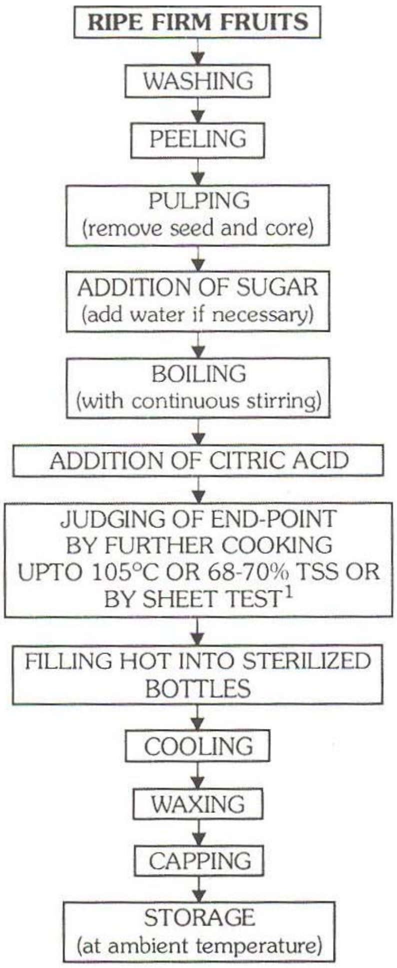
- The amount of soluble solids in the form of citric acid and KMS is

Citric acid @ 0.5%, in the final produce is 50 g i.e. 0.05 kg.

- Amount of solids to be added in the form of sugar is 4.55–0.05=4.5 kg.

- Add the calculated amount pulp and sugar to about 2 lts of water and boil it to 105°C so that the sugar dissolves completely. Add citric acid and juice to the sugar syrup and judge the end point by measuring its TSS or using sheet test.

Flow sheet



1. **Sheet or flake test:** A small portion of jam is taken out during boiling, in a spoon or wooden ladle and cooled slightly. It is then allowed to drop. If the product falls off in the form of a sheet or flakes instead of flowing in a continuous stream or syrup, it means that the end-point has been reached and the product is ready, otherwise, boiling is continued till the sheet test is positive.

b) Jelly

- A jelly is a semi-solid product prepared by boiling a clear, strained solution of pectin-containing fruit extract, free from pulp, after the addition of sugar and acid.

- A perfect jelly should be transparent, well-set, but not too stiff, and should have the original flavour of the fruit. It should be of attractive colour and keep its shape when removed from the mould. It should be firm enough to retain a sharp edge but tender enough to quiver when pressed.

- It should not be gummy, sticky or syrupy or have crystallized sugar. The product should be free from dullness, with little or no syneresis (weeping), and neither tough nor rubbery.

- Guava, sour apple, plum, karonda, wood apple, loquat, papaya, and gooseberry are generally used for preparation of jelly. Apricot, pineapple, strawberry, raspberry, etc., can be used but only after addition of pectin powder, because these fruits have low pectin content. Its acid content should be 0.5-0.75%.

Method of preparation

For the preparation of 10 kg of jelly follow the procedure given below:

- Take about 10 kg of fruit and boil in 15 lts of water for 20 – 30 min.

- Add to it about 20 g (@ 2g/kg) of citric acid and strain it.

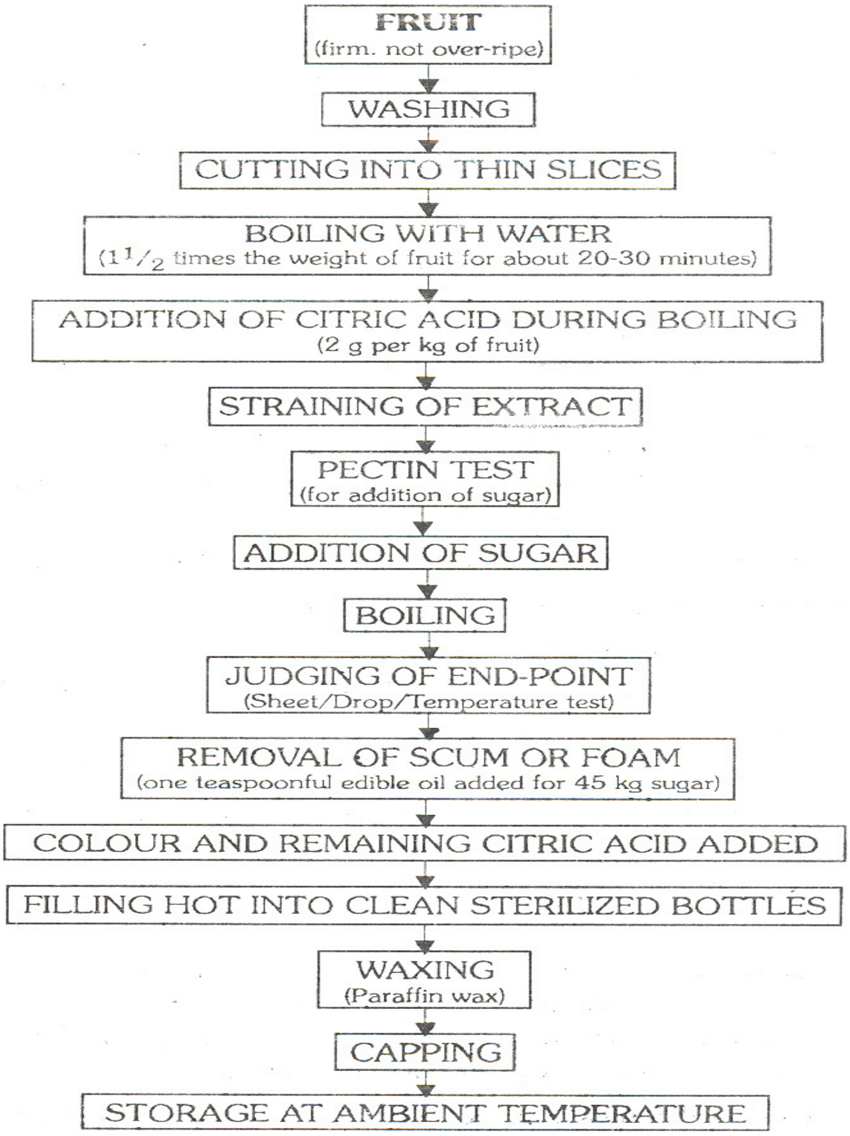
- Determine the pectin content using alcohol or Jelmeter test.

- Add the required amount of sugar (1:1 for extracts rich in pectin; 1:0.75 for extract moderate in pectin; and 1:0.5 for extract poor in pectin.

- Boil the mixture judge the end point using sheet test as mentioned in the preparation of jam.

- Add the calculated amount pulp and sugar to about 2 lts of water and boil it to 105°C so that the sugar dissolves completely. Add citric acid and juice to the sugar syrup and judge the end point by measuring its TSS or using sheet test.

Flow sheet



c) Preserve and its Method of Preparation

- A mature fruit/vegetable or its pieces impregnated with heavy sugar syrup till it becomes tender and transparent is known as a preserve.
- Aonla, bael, apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, etc., can be used for making preserves.
- It can be prepared using 1 kg of fruit, 1 litre of water and 1 kg of sugar. A. little quantity of acid (citric or tartaric) is added during the preparation to prevent crystallization of the syrup.

Method of preparation

The following steps are required in a good preserve:-

1. Pre-treatment
2. Leaching
3. Pricking
4. Penetration of Sugar
5. Finishing

1. Pre-treatment

After selecting good fruit, it is washed and given pretreatment for the following functions

a) To reduce bitterness
b) Softening and Maturity
c) Hardening the tissues
d) Storing for long period
e) Reducing the shrinkage of fruit

2. Leaching

Leaching is carried out in the following functions:

a) To remove salty taste from fruit
b) To soften the fruit so that penetration is quick
c) To remove bitterness in intercellular space

3. Pricking

a) Pricking is carried out for facilitating of the penetration of sugar.
b) This is usually done by piercing fork needles or stamp having painted nails or needle.

4. Penetration of Sugar

This is done to achieve the following:

a) Uniform penetration
b) Retention of natural colour and flavour
c) Retention of nutrition
d) Method should be quick

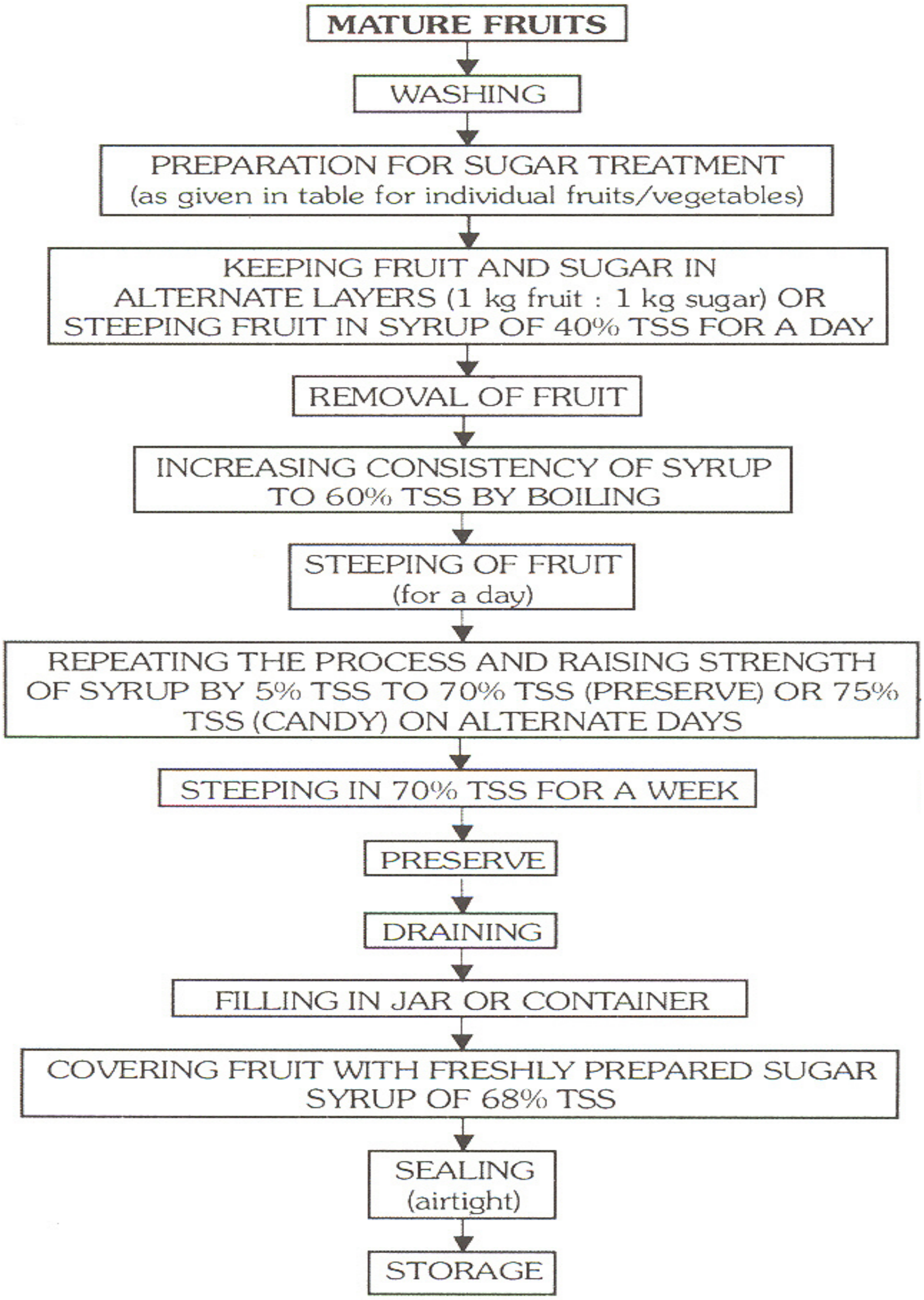
5. Finishing

Generally preserve is packed along with syrup covering 45% portion in the container.

For the preparation of 10 kg of jelly follow the procedure given below:

- Take about 10 kg of fruit and prepare it for sugar treatment as mentioned in the table in the following section.
- Make 10 lts of sugar solution of 40% TSS (Dissolve 4 kg of sugar in about 5 lts of water and make up the volume to 10 lts.).
- Dip the fruit in the sugar syrup for 24 hrs. Remove the fruit and boil the sugar solution to increase its consistency to 60%. Again steep the fruits in it for 24 hrs.
- Repeat the process on alternate days raising the TSS % of the sugar solution by 5% up to 70%. Steep the fruits in 70% TSS sugar solution for a week and the preserve is ready.
- The preserve should be stored in air tight jars with adequate sugar solution of 68% TSS to cover the fruits.

Flow sheet


MATURE FRUITS
WASHING
PREPARATION FOR SUGAR TREATMENT (as given in table for individual fruits/vegetables)
KEEPING FRUIT AND SUGAR IN ALTERNATE LAYERS (1 kg fruit : 1 kg sugar) OR STEEPING FRUIT IN SYRUP OF 40% TSS FOR A DAY
REMOVAL OF FRUIT
INCREASING CONSISTENCY OF SYRUP TO 60% TSS BY BOILING
STEEPING OF FRUIT (for a day)
REPEATING THE PROCESS AND RAISING STRENGTH OF SYRUP BY 5% TSS TO 70% TSS (PRESERVE) OR 75% TSS (CANDY) ON ALTERNATE DAYS
STEEPING IN 70% TSS FOR A WEEK
PRESERVE
DRAINING
FILLING IN JAR OR CONTAINER
COVERING FRUIT WITH FRESHLY PREPARED SUGAR SYRUP OF 68% TSS
SEALING (airtight)
STORAGE

Preparation of fruits and vegetables for preparing preserve

Fruit/ vegetable	Steps of Process			
	Step I	Step II	Step III	Step IV
1	2	3	4	5
Aonla	Prick with fork, needle or gooseberry pricker (avoid iron needle as it causes browning due to tannin in fruit)	Steep in 2% salt solution for 24 hours to remove astringency	Wash and dip in 2% alum solution for 24 hours then wash thoroughly	Blanch until soft but segments do not break or crack
Apple and pear	Peel, prick with needle or fork (do not remove core and stem of whole fruit to be used otherwise peel and cut into halves or quarters, remove core and prick)	Steep in 2% salt solution for 24 hours to prevent browning and disintegration of fruit tissues during blanching	Wash and dip in 2% alum solution for 24 hours and wash again	Blanch in water containing small quantity of potassium metabisulphite to bleach or in water containing edible deep green or red colour
Bael	Remove shell, slice peeled fruit crosswise into 2.5 cm thick pieces and wash with water, prick on both sides	Steep in cold water for 24 hours	-	Blanch in water containing edible red colour until soft and sufficient colour absorbed
Ber	Prick whole fruit	Steep in 2% salt solution containing 0.2% potassium metabisulphite for a week and wash thoroughly	-	Blanch until soft
Mango	Peel and remove green portion (because it turns black during subsequent operations), cut fruit lengthwise into large pieces	-	-	Blanch until soft and then prick pieces
Karonda and Cherry	Cut into two pieces and remove seeds	Steep in 2% salt solution containing 600 ppm sulphur dioxide (in orm of potassium metabisulphite) for 24 ours to bleach, thereafter wash and prick with fork	-	Blanch in water containing 0.05% erythrosine and 0.25% citric acid to soften sufficiently and fix the artificial colour

Pineapple	Peel, cut into 1cm slices, remove core and eyes, prick slices on both sides	Steep in 2% salt solution for 24 hours	Wash and steep in cold water for 12 hours	Blanch until soft
Papaya	Peel, cut into rectangular pieces 4 cm long and 0.5-1.0 cm thick, remove seeds and prick	Steep in 2% salt solution for 24 hours	Wash thoroughly	Blanch until soft
Strawberry and Raspberry	Remove stems	-	-	Blanch for a minute
Petha (Ash gourd)	Cut lengthwise into large pieces, remove fluffy portion, peel, prick and cut into pieces of suitable size	Soak in dilute lime water for 24 hours to harden texture	Wash and soak in 2% alum solution for 24 hours and a wash again	Blanch (until tender) in water containing little potassium metabisulphite to bleach
Ginger	Scrape off skin from tender, fibreless, large sized rhizomes, and cut into pieces	-	-	Boil for an hour with 0.5% citric acid solution (to improve colour) in pressure cooker, then prick and wash
Carrot	From tender carrot having soft pith, scrape off thin peel and green leafy portion, prick and cut into suitable sized pieces	-	-	Blanch until soft
Citrus peel	Remove the rags from thick rind orange, citron, pummelo, etc.	Dip in 2% hot sodium bicarbonate solution for 30 minutes, then wash and prick	-	Blanch until tender and to remove bitterness

CANDIES – Glaced and Crystallized

Principles

Candy is fruit penetrated with sugar and dried to give a sugar coated solid fruit pieces. The glaced candy are coated with a thin transparent layer of heavy sugar syrup, while crystallized candy are derived from coating pure white crystallized sugar. In preparing candies all steps are same as that up preserve except that of finishing.

Fruit butters

This product is prepared by boiling the fruit pulp with or without the addition of sugar, fruit juices and spices to a semi-solid mass of homogeneous consistency. It differs from jam in being of higher concentration and finer consistency. It is usually heavily spiced. The appearance and texture look like butter. They are packed in can and sterilized in boiling water.

Fruit confections

This is a general term used to describe candies in which fruits are used. They are on the market a large number of products of the character which vary greatly in appearance, texture, flavour and the proportion of fruit used in their manufacture.

Guava jelly and cheese

Guava are available plenty and cheap during the season all over India. It is rich source of Vitamin C. You can prepare jelly and thereafter cheese from residue of fruit. Jelly is prepared from the extract of the fruit.

Recipe in cheese

Pulp 1 kg Sugar 1.25 kg Salt 3g Butter 20g	Cook sugar and pulp till it becomes very thick add salt, butter and continue cooking till it does not stick to bottom of the vessel. Smear a tea spoon of ghee on tray and spread cooked guava pulp. When it is cold roll out glass jar to make surface smooth. Next day cut into small pieces and wrap them into Butter paper.

2.2.4 Observations

Determine TSS, acidity, pectin (alcohol method/jelmeter test) and consistency of gel (sheet/flake test).

Note: The procedure for the calculation of TSS, acidity, pectin (alcohol method/jelmeter test) and consistency of gel (sheet/flake test) can be seen in the practical manual of Course III 'Food Chemistry and Physiology' and theory of course IV 'Food Processing and Engineering – I'.

2.2.5 Result

Acidity of the given jam, jelly, preserve = % (w/v)

TSS of the given jam, jelly, preserve = %

2.3 PRECAUTIONS

- All equipment used in the preparation of fruit juices and squashes should be rust and acid proof.
- Copper and iron vessels should be strictly avoided as these metals react with fruit acids, and cause blackening of the product.

EXPERIMENT 3 PREPARATION OF PICKLES AND CHUTNEYS, RELISHES AND SAUCES

Structure

3.1 INTRODUCTION

Pickling is the result of fermentation by lactic acid-forming bacteria, which are generally present in large numbers on the surface of fresh vegetables and fruits. These bacteria can grow in acid medium and in the presence of 8-10 % salt solution, whereas the growth of a majority of undesirable organisms is inhibited. Lactic acid bacteria are most active at 30°C, so this temperature must be maintained as far as possible in the early stage of pickle making. When vegetables are placed in brine, the brine penetrates into the vegetable tissues and soluble material present in them diffuses into the brine by osmosis. The soluble material includes fermentable sugars and minerals. The sugars serve as food for lactic acid bacteria that in turn convert the sugars into lactic and other acids. The acid brine thus formed acts upon vegetable tissues to produce the characteristic taste and aroma of pickle. Pickles are consumed as minor item in food to make meals more a) appetizing, b) digestive, c) antiseptic due to the presence of spices, d) supplying protective food as vitamins and minerals. The commercial varieties of pickles can be divided into five classes.

1. Fermented Pickle
2. Oil Pickle
3. Acid Pickle
4. Mustard Pickle
5. Brine Pickle

Out of five classes only first four are sold in form of finished pickle where as the last one mainly brine pickle is generally not sold for consumer but is kept for further processing to make other types of pickle.

Objectives

After going through this experiment, you should be able to:

- know the pickling processes by pickling the available fruits and vegetables;
- describe the methods of chutney, relishes and sauces; and
- explain the precautions during the processes of product making.

3.2 EXPERIMENT

3.2.1 Principle

Pickles and chutneys are prepared with salt, vinegar, oil or with a mixture of salt, oil, spices and vinegar.

3.2.2 Requirements

Raw materials, equipment and apparatus

1. Fruit/vegetable, sugar
2. Peeler
3. Juicer
4. Pulper
5. Filter cloth / sieve
6. Pans of suitable size
7. Heaters
8. Thermometer
9. Crown corking / capping machine
10. Corks / caps
11. Volumetric flask
12. Measuring cylinder
13. Weighing balance
14. Potable water

Chemicals and reagents

1. Hydrochloric acid
2. Citric acid / ascorbic acid
3. Potassium metabisulphite
4. Sodium benzoate

3.2.3 Procedure

a) Pickles and its Method of Preparation

Pickles are prepared with salt, vinegar, oil or with a mixture of salt, oil, spices and vinegar. The general process for the preparation and preservation of is as under:

1. Preservation with salt

Salt improves the taste, flavour and hardness of the tissues of vegetables and controls fermentation. Salt content of 15 % or above prevents microbial spoilage. This method of preservation is generally used only for vegetables which contain very little sugar and hence sufficient lactic acid cannot be formed by fermentation to act as preservative. However, some fruits like lime, mango, etc., are also preserved with salt. The preparation of some pickles is described below:

i) Lime pickle: Lime 1 kg, salt 200 g, red chilli powder 15 g, cinnamon, cumin, cardamom (large) and black pepper (powdered) each 10 g, clove (headless) 5 numbers.

PROCESSING FLOW-SHEET FOR LIME PICKLE

LIMES
↓
WASHING
↓
CUTTING INTO 4 PIECES
↓
SQUEEZING OUT JUICE FROM 1/4 AMOUNT OF FRUIT
↓
MIXING SPICES AND SALT WITH JUICE
↓
MIXING WITH LIME PIECES
↓
FILLING IN JARS
↓
COVERING WITH LID
↓
KEEPING IN SUN FOR 4-6 DAYS
(shaking jar at least twice a day)
↓
STORAGE AT AMBIENT TEMPERATURE
(in cool and dry place)

ii) *Mango pickle:* Mango peeled and sliced 1 kg, salt 200 g, red chilli powder 109, asafoetida 5 g, fenugreek, black pepper, cardamom (large), cumin and cinnamon (powdered) each 109, clove (headless) 6 numbers.

PROCESSING FLOW-SHEET FOR MANGO PICKLE

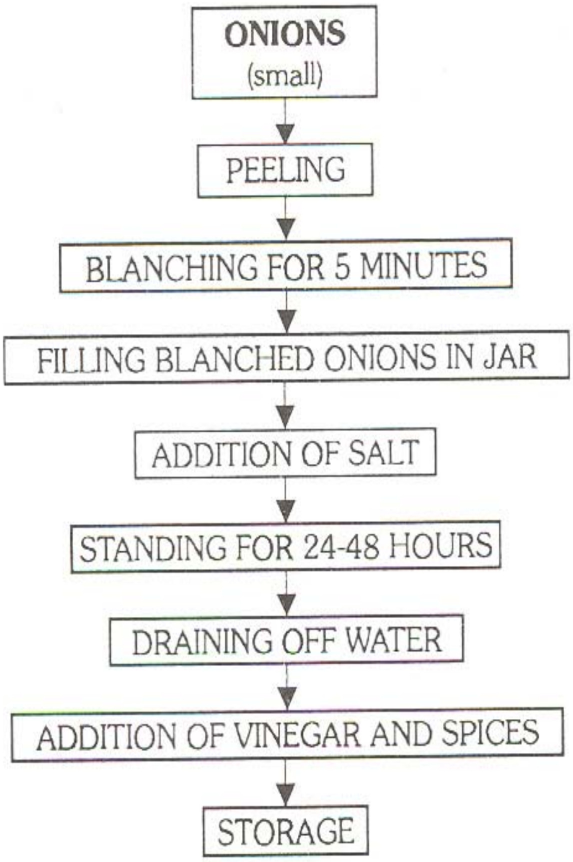
MANGOES
(mature, green)
↓
WASHING
↓
PEELING
↓
SLICING
↓
PUTTING SLICES IN JAR
↓
SPRINKLING SALT
↓
PUTTING IN SUN FOR ONE WEEK
(shaking jar at least twice a day to mix the salt)
↓
MIXING SPICES
↓
STORAGE AT AMBIENT TEMPERATURE
(in cool and dry place)

2) *Preservation with vinegar*

A number of fruits and vegetables are preserved in vinegar whose final concentration, in terms of acetic acid, in the finished pickle should not be less than 2 %. To prevent dilution of vinegar below this strength by the water liberated from the tissues, the vegetables or fruits are generally placed in strong vinegar of about 10 % strength for several days before pickling. This treatment helps to expel the gases present in the intercellular speces of vegetable tissue. Vinegar pickles are the most important pickles consumed in foreign countries. Mango, garlic, chillies, etc., are preserved as such in vinegar.

i) *Onion pickle:* Onions 1 kg, vinegar 1 litre, salt 250 g, red chilli powder 10 g, cardamom (large), black pepper, cumin (powdered) each 10 g, clove (headless) 5 numbers.

PROCESSING FLOW-SHEET FOR ONION PICKLE

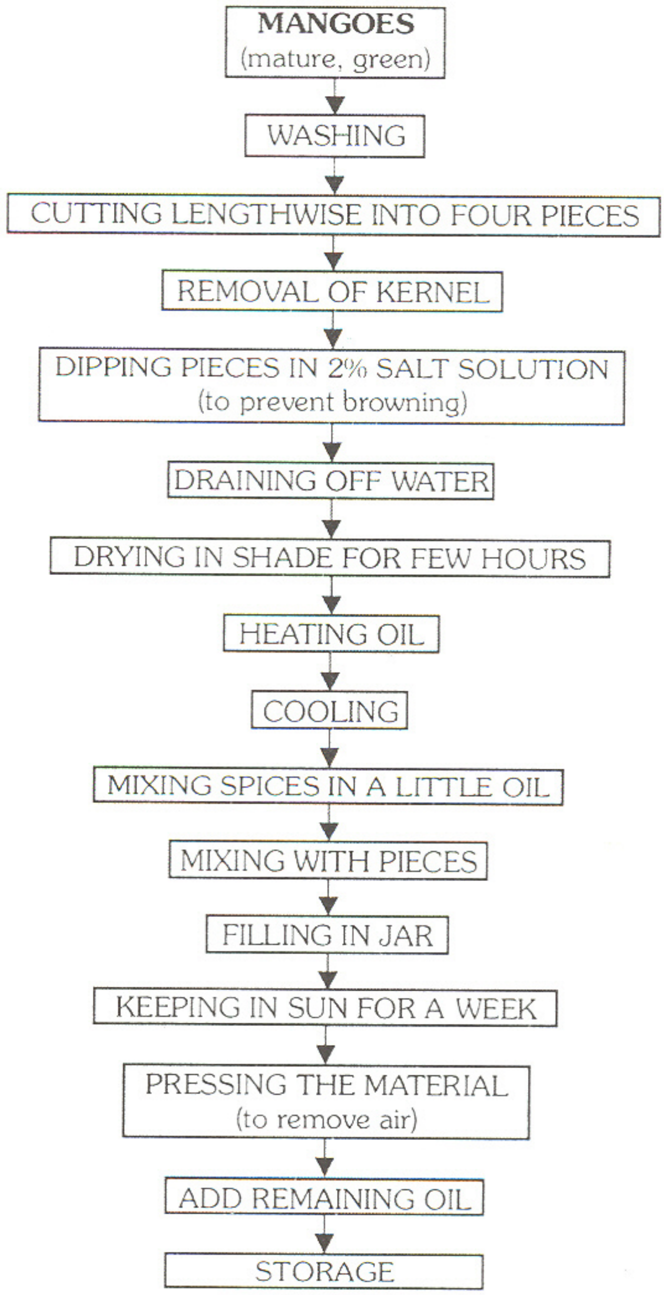


3) *Preservation with oil*

The fruits or vegetables should be completely immersed in the edible oil. Cauliflower, lime, mango and turnip pickles are the most important oil pickles.

i) *Mango pickle:* Mango pieces 1 kg, salt 150g, fenugreek (powdered) 25g, turmeric (powdered) 15 g, nigella seeds 15g, red chilli powder 10g, clove (headless) 8 numbers, black pepper, cumin, cardamom (large), aniseed (powdered) each 15g, asafoetida 2g, mustard oil 350 ml Gust sufficient to cover pieces).

PROCESSING FLOW-SHEET FOR MANGO PICKLE



b) Chutney and its Method of Preparation

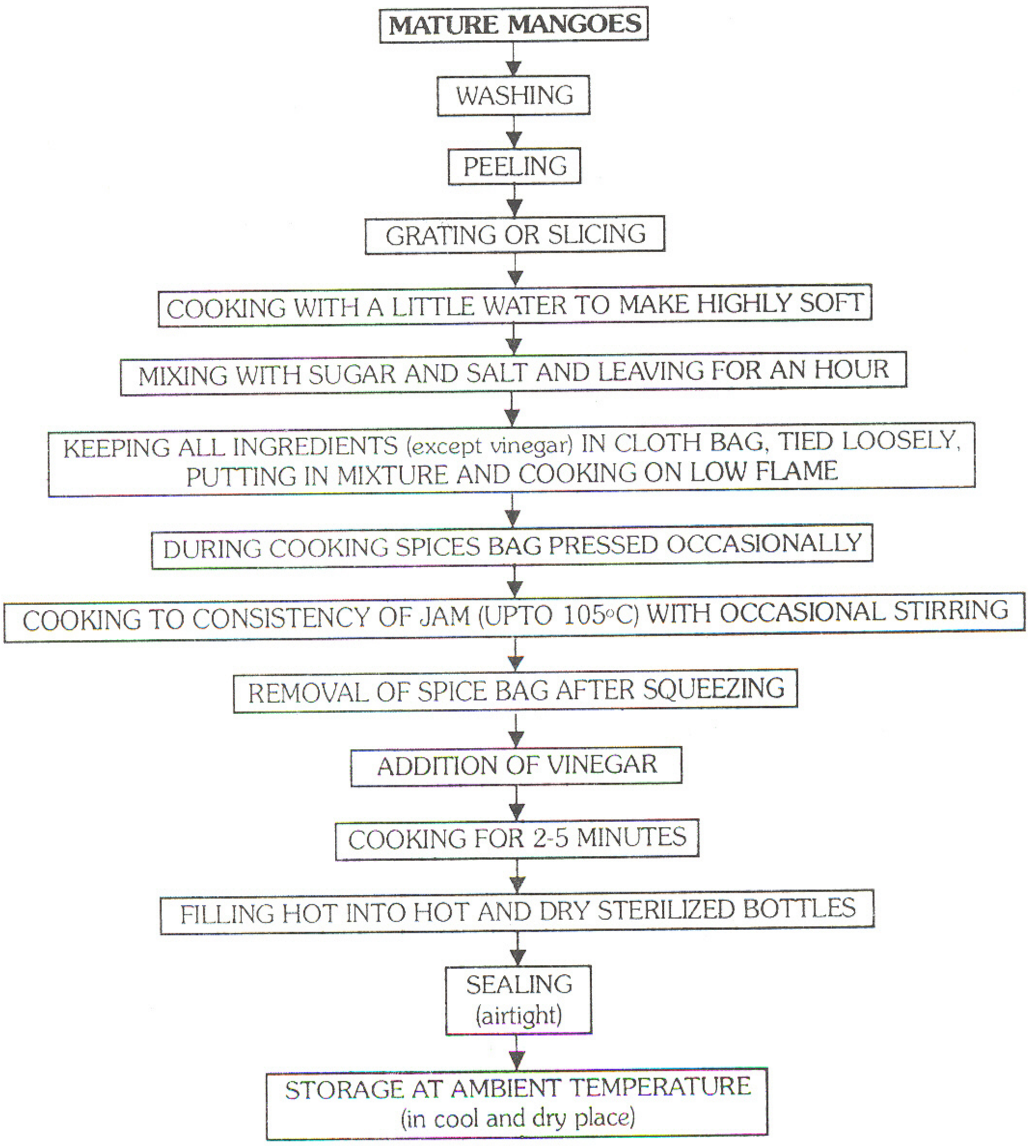
- The method of preparation of chutney is similar to that for jam except that spices, vinegar and salt are added.
- The fruits/vegetables are peeled, sliced or grated, or cut into small pieces and cooked in water until they become sufficiently soft.
- The quality of a chutney depends to a large extent on its cooking which should be done for a long time at a temperature below the boiling point.
- To ensure proper thickening, cooking is done without a lid even though this results in some loss of volatile oils from the spices.
- Chopped onion and garlic are added at the start to mellow their strong flavours. Spices are coarsely powdered before adding.

- Vinegar extract of spices may be used instead of whole spices. Spice and vinegar are added just before the final stage of cooking, because prolonged boiling causes loss of some of the essential oils of spices and of vinegar by volatilization.
- In mango and apricot sweet chutneys, where vinegar is used in large quantity, the amount of sugar added may be reduced because vinegar itself acts as a preservative.
- The chutneys are cooked to the consistency of jam to avoid fermentation. Some of the common recipes for preparation of chutney are given below.

1. *Sweet mango chutney*

   Mango slices or shreds 1 kg, sugar 1 kg, salt to taste, onions (chopped) 50g, garlic (chopped) 15g, ginger (chopped) 15g, red chilli powder 10g, black pepper, cardamom (large), cinnamon, cumin, aniseed (powdered) 10g each, clove (headless) 5 numbers and vinegar 170 ml.

PROCESSING FLOW-SHEET FOR SWEET MANGO CHUTNEY



2. *Apple chutney*

Apple slices 1 kg, sugar 750 g, dried dates (chopped) 100g, salt to taste, raisins 50g, ginger (chopped) 15g, red chilli powder 10g, black pepper, cardamom (large), cinnamon, cumin, aniseed (powdered) 10g each, clove (headless) 5 numbers, onions (chopped) 250g, garlic (chopped) 15g, and vinegar 200 ml.

PROCESSING FLOW-SHEET FOR APPLE CHUTNEY

APPLES
↓
WASHING
↓
PEELING
↓
REMOVAL OF CORES
↓
FINE SLICING
↓
COOKING SLICES WITH ONION AND SALT TILL SOFT
↓
ADDITION OF ALL INGREDIENTS
(except sugar and vinegar) AND COOKING GENTLY TO DESIRED CONSISTENCY
↓
ADDITION OF SUGAR AND COOKING TO THICK CONSISTENCY
↓
ADDITION OF VINEGAR AND COOKING FOR 5 MINUTES
↓
FILLING HOT INTO BOTTLES
↓
SEALING
↓
STORAGE AT AMBIENT TEMPERATURE
(in cool and dry place)

3. *Apricot chutney*

Apricot slices 1 kg, sugar 1 kg, salt to taste, onions (chopped) 50g, garlic (chopped) 10g, ginger (chopped) 20g, red chilli powder 10g, black pepper, cardamom (large), cinnamon, cumin, aniseed (powdered) 10g each, clove (headless) 5 numbers and vinegar 150 ml.

PROCESSING FLOW-SHEET FOR APRICOT CHUTNEY

APRICOTS
(ripe)
↓
WASHING
↓
SLICING
↓
MIXING SUGAR AND LEAVING FOR AN HOUR
↓
REST OF PROCESS SIMILAR TO THAT FOR SWEET MANGO CHUTNEY
EXCEPT THAT SALT IS MIXED WHEN VINEGAR IS ADDED
AT THE END OF PROCESS

c) Relish

Relish is a semi solid or vinegar extract prepared by mixing fruit or vegetable pulp and used in making food more flavourful and relishing. It can also include the sauces and chutney.

In the preparation of relish mayonaise comes fore most. The next comes is mustard paste and third one is spice vinegar.

Mayonaise

Recipes	1kg Salad oil	Preparation Egg yolk and oil is beaten together and kept aside spiced vinegar is taken and mixed with the mixture of oil and egg yolk. Add sugar to the mixture. Gum tragcanth can be used as stablizer in immulsion.
	100g egg yolk	
	1 kg vinegar spiced	
	100 g sugar	
	Sod. Benzoat 200 ppm	

Mustard paste

The mustard paste is prepared by mixing mustard powder with spiced vinegar to make a smooth paste. It is preserved with 0.05% BHA and 250ppm sodium benzoat.

Spiced Vinegar is nothing but malt vinegar infused with spices and herbs. Whole spices are put in a muslin bag and suspended for 3-4 days. After that it is simmered and spiced oils are added.

d) Sauces

Sauces are made from fruit/vegetable pulps, flavoured with vinegar and spices. There are two types of sauces namely 1) Thin sauces and 2) Thick sauces.

Thin sauces: Thin sauces are those where the flavour of spices, grains fruits, vegetables are extracted in Vinegar. The most popular in this category are a) Worestershire Sauce, b) Soya Sauce, c) Walnut Ketchup.

Thick sauces: Thick sauces are those where spices, vinegar, sugar and starch are mixed with fruit and vegetable pulps. They are concentrated to desired consistency. Thick sauces are generally prepared from tomatoes or from vegetables.

Vinegar: It is one of the ingredient used in pickles its types are given in Annexure I.

3.2.4 Observation

Determine TSS, acidity and salt.

3.2.5 Result

TSS, acidity and salt = %

3.3 PRECAUTIONS

- All equipment used in the preparation of fruit juices and squashes should be rust and acid proof.
- Copper and iron vessels should be strictly avoided as these metals react with fruit acids, and cause blackening of the product.
- The spices should be free from foreign matter and microbial contamination.

EXPERIMENT 4 PRODUCTION OF TOMATO JUICE, KETCHUP, PUREE AND PASTE

Structure

4.1 INTRODUCTION

Tomato is grown in our country in abundance, both in summer and winter seasons, but those grown in winter are superior in quality because they contain more total solids. They are a good source of vitamin C. Often they are sold at distress prices during the peak harvest season and nearly 25% of the produce is spoiled due to mishandling. Such losses can be avoided by converting tomatoes into delicious products like paste, puree, juice, ketchup and sauce. This processing of tomato will not only minimize the chances of distress sale but also permit the growers/ their dependents to generate more income.

The quality of a tomato product is judged by its colour, which is dependent on the redness of the tomatoes used. In fact, the red pigment (lycopene) can be used as an index of the amount of tomato actually present in a product. High quality tomato products can be prepared only by: (i) using plant-ripened uniformly red tomatoes as the yellow and greenish portions not only mask the red colour but also cause browning due to oxidation; (ii) avoiding prolonged heating, and cooling the product quickly after preparation; and (iii) not using iron and copper equipment at any stage of processing. Lycopene (self-oxidizing isomer of carotene) turns brown when it comes into contact with iron. Iron also forms black compounds with the tannin in the tomatoes and the spices used. Equipment used should be glass-lined or made of stainless steel.

Objectives

After going through this experiment, you should be able to:

- understand the general concepts of tomato processing and those of processed products;
- know the flow charts of production methodologies; and
- explain experience in the production of tomato juice, ketchup, puree and paste.

4.2 EXPERIMENT

4.2.1 Principle

Tomato products are prepared from ripe tomatoes and preserved by chemical preservatives or by heat application.

4.2.2 Requirements

Raw materials, equipment and apparatus

1. Tomato, spices, etc.
2. Pulper
3. Filter cloth / sieve
4. Pans of suitable size
5. Heaters
6. Thermometer
7. Crown corking / capping machine
8. Corks / caps
9. Sterilizer/Pasteurizer
10. Volumetric flask
11. Measuring cylinder
12. Weighing balance
13. Potable water

Chemicals and reagents

1. Salt
2. Sugar
3. Citric acid/Vinegar
4. Spices

4.2.3 Procedure

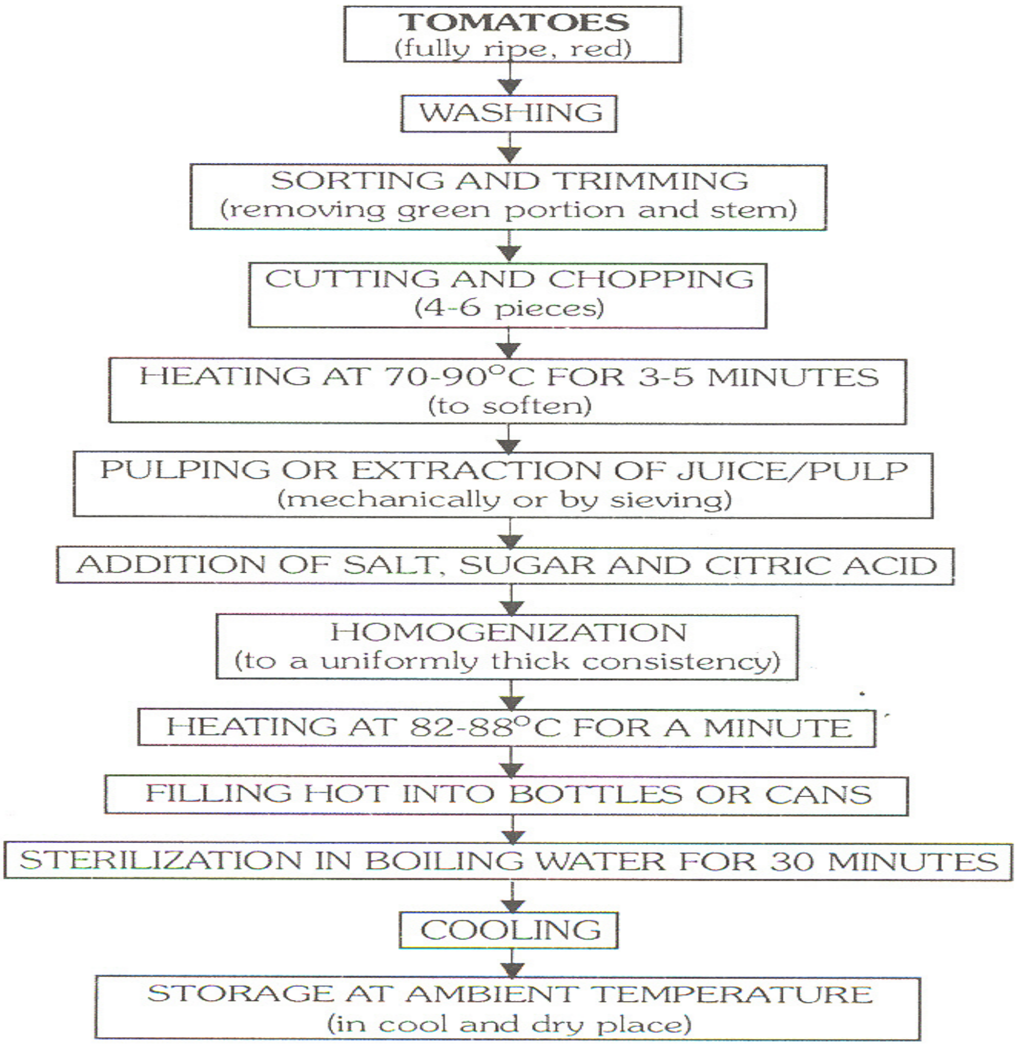
a) Tomato Juice

Plant-ripened, fully red fruits are selected, discarding all green, blemished and over-ripe fruits. A good quality juice should be of deep red colour, possess the characteristic taste and flavour of tomato, contain about 0.4 % acid (in terms of citric acid), be uniform in appearance and have high nutritive value. In addition the juice should contain 0.5% salt, and 1% sugar.

An average of 10 kg of tomatoes yields 7 litres of juice. Wash tomatoes, remove stems, and trim off bruised or discoloured portions. To prevent juice from separating, quickly cut about 0.5 kg of fruit into quarters and put directly into saucepan. Heat immediately to boiling while crushing. Continue to add and crush freshly cut tomato quarters to the boiling mixture. Make sure the mixture boils constantly and vigorously while you add the remaining tomatoes. Simmer 5 min. after you add all pieces. Press heated tomatoes through a sieve or food mill to remove skins and seeds. Heat juice again to boiling.

Hot pulping is superior to cold pulping because in the latter case, extraction of juice is somewhat difficult and its yield is less, vitamin C is oxidized more rapidly, the juice is lighter in colour and there are chances of microbial spoilage. On commercial scale, a pulper or continuous spiral press is used for juice extraction but in homes tomatoes are strained through a steel sieve. To one litre of juice add 10g of sugar, 5g of salt, 1g of citric acid and 1g of sodium benzoate. Herbs, onion, garlic, and spices may be added to meet individual's taste requirements.

PROCESSING FLOW-SHEET FOR TOMATO JUICE



b) Tomato Sauce/Ketchup

It is made from strained tomato juice or pulp and spices, salt, sugar and vinegar, with or without onion and garlic, and contains not less than 12% tomato solids and 25% total solids.

General considerations: About one-third of the sugar required is added at the time of commencement of boiling to intensify and fix the red tomato colour. If the whole quantity of sugar is added initially, the cooking time will be longer and the quality of pulp will be adversely affected. Generally, the sugar content in ketchups/sauces varies from 10-26%. On the other hand, salt bleaches the colour of the tomato product. It is, therefore, desirable to add it towards the end of the cooking process. Spices are generally added in powdered form to the product by spice bag method. Instead of whole spices, essential oils of spices, oleoresins and spice extract can also be used. Essential oils, however, do not give the characteristic true aroma of whole spice but oleoresins provide true aroma. At present, spice extract is used in many industries for sauce/ketchup preparations. These do not adversely affect the colour of the product and are generally added a few minutes before the end of cooking.

The salt content of the product should be 1.3-3.4%. Good quality vinegar is essential for the preparation of high quality sauce/ketchup. It should contain 5.0-5.5% acetic acid and should be added when the product has thickened sufficiently, so that the acid is not lost by volatilization. Tomato sauce/ ketchup generally contains 1.25-1.5% acetic acid. Sometimes glacial acetic acid (100% acetic acid) is used which is colourless and cheaper than vinegar. In order to increase the viscosity and prevent the separation of pulp form clear juice, pectin can be added to the extent of 0.1-0.2% by weight of the finished product. The ketchup should be filled hot (about 88°C) to prevent browning and loss of vitamins during subsequent storage. If it is made from tomatoes of good quality, using sugar, salt, vinegar and spices in the correct proportion, it does not spoil for a fairly long time, even after opening the sealed bottle, if the latter is kept in a cool and clean place. It is, however, advisable to add 0.025% sodium benzoate to the product before bottling and then pasteurize the bottles as a precaution against spoilage during the 3 to 4 weeks that the ketchup remains in the opened bottle before it is used up.

Recipe: Tomato pulp 1 kg, sugar 75g, salt 10g, onion (chopped) 50g, ginger (chopped) 10g, garlic (chopped) 5g, red chilli powder 5g, cinnamon, cardamom (large), aniseed, cumin, black pepper (powdered) 10g each, clove (headless) 5 numbers, vinegar 25 ml or glacial acetic acid 5 ml and sodium benzoate 0.25g per kg final product.

PROCESSING FLOW-SHEET FOR TOMATO SAUCE/KETCHUP

TOMATOES
(fully ripe, red)

↓

WASHING

↓

SORTING AND TRIMMING

↓

CUTTING AND CHOPPING

↓

HEATING AT 70-90°C FOR 3-5 MINUTES
(to soften)

↓

PULPING OR EXTRACTION OF JUICE/PULP
(mechanically or by sieving)

↓

STRAINING TOMATO PULP/JUICE

↓

COOKING PULP WITH ONE-THIRD QUANTITY OF SUGAR

↓

PUTTING SPICE BAG IN PULP AND PRESSING OCCASIONALLY

↓

COOKING TO ONE-THIRD OF ORIGINAL VOLUME OF PULP/JUICE

↓

REMOVAL OF SPICE BAG
(after squeezing in pulp)

↓

ADDITION OF REMAINING SUGAR AND SALT

↓

COOKING

↓

JUDGING OF END-POINT
(tomato solids by hand refractometer/volume by measuring stick, i.e., one-third of its original volume)

↓

ADDITION OF VINEGAR/ACETIC ACID AND PRESERVATIVE

↓

FILLING HOT INTO BOTTLES AT ABOUT 88°C

↓

CROWN CORKING

↓

PASTEURIZATION
(at 85-90°C for 30 minutes)

↓

COOLING

↓

STORAGE AT AMBIENT TEMPERATURE
(in cool and dry place)

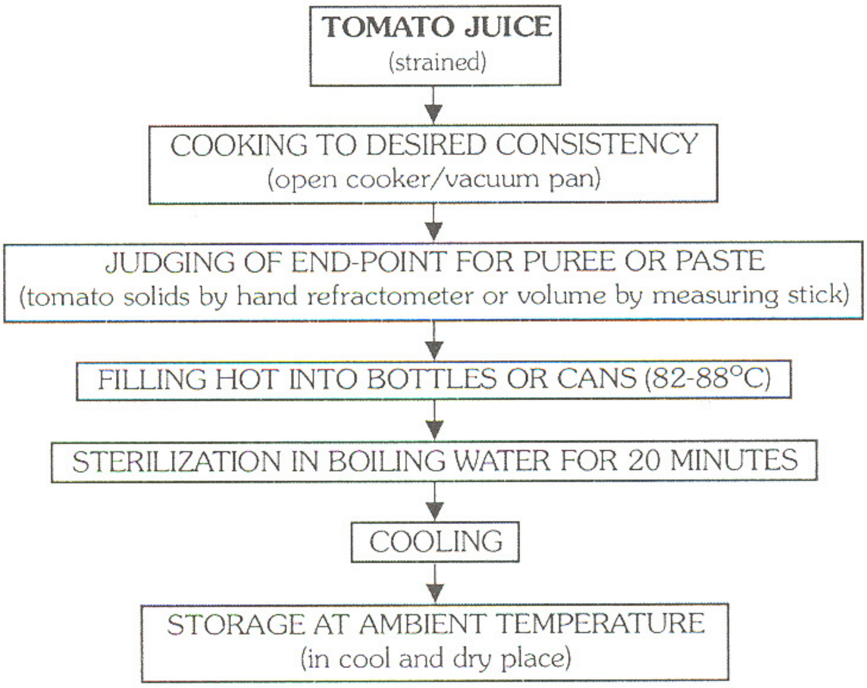
c) Tomato Puree and Paste

Concentrated tomato pulp without skin or seeds, with or without added salt, and containing not less than 9.0 % of salt-free tomato solids, is known as 'medium tomato puree'. It can be concentrated further to 'heavy tomato puree', which contains not less than 12% solids. If this is further concentrated so that it contains not less than 25% tomato solids, it is known as tomato paste. On further concentration to 33% or more of solids, it is called concentrated tomato paste.

Tomato pulp is prepared from plant ripened tomatoes in the same manner as tomato juice. Cooking for concentration of the pulp can be done either in an open cooker or a vacuum pan. In the former most of the vitamins are destroyed and the product become brown. On the other hand, use of vacuum pans, which are expensive, help to preserve the nutrients and also reduce the browning to a great extent. In vacuum pans the juice is boiled at about 71°C only. Ordinarily tomato juice can be concentrated to 14-15% solids in an open cooker, but for obtaining higher concentrations a vacuum pan is required. Moreover, sterilization of the product is also possible in a vacuum pan. While cooking in an open cooker, a little butter or edible oil is added to prevent foaming, burning and sticking.

If, after cooking, the total solids content of the juice is higher than required, more juice is added to lower it, if it is lower, cooking is continued till the desired concentration is reached. The end-point of cooking puree and paste can be determined either with a hand refractometer or by measuring the volume (a known volume of juice is concentrated to a known volume of final product) with the help of a measuring stick.

PROCESSING FLOW-SHEET FOR TOMATO PUREE/PASTE



d) Tomato Cocktail

Tomato cocktail is gaining popularity in many high class hotels and restaurants. It is prepared before serving and is also served from stock. The cocktail is preserved by pasteurizing it in bottles. The main constituent is tomato juice to which tobasco sauce, common salt, vinegar, lemon, worcestershire sauce are added in different proportions to suit the palate.

e) Chili Sauce

This is highly spiced product and is prepared from plant-ripened and peeled tomatoes. It is mostly used as a flavouring material in cooking and to some extent as a table relish also.

f) Tomato Soup

The main constituents of the soup are tomato juice, butter or cream, spices, arrowroot (a thickening agent), etc. These are added in various proportions to suit the table.

4.2.4 Observations

Determine TSS and acidity.

4.2.5 Result

Acidity of the tomato product	=	% (w/v)
TSS of the tomato product	=	%

4.3 PRECAUTIONS

- All equipment used in the preparation of fruit juices and squashes should be rust and acid proof.
- Copper and iron vessels should be strictly avoided as these metals react with fruit acids, and cause blackening of the product.
- Avoid exposure of juice to atmosphere as it will spoil the colour, taste and aroma and also reduce the Vitamin content.

EXPERIMENT 5 DRYING AND DEHYDRATION OF FRUITS AND VEGETABLES

Structure

5.1 INTRODUCTION

Dehydration is an age-old method of preservation of fruits and vegetables by removal of moisture. It is the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, humidity and air flow. Various factors that affect the rate of drying of fruits and vegetables include the following:

i) Composition of raw materials
ii) Size, shape and arrangement of stacking of produce
iii) Temperature, humidity and velocity of air
iv) Pressure (barometric or under –vacuum)
v) Dehydration technique

Depending upon the type of dryers and drying environments available, the drying studies could be conducted.

The dried product could either be consumed directly or it needs to be rehydrated before use. For example, most vegetables need to be rehydrated. The practical will permit the study of rehydration behavior of the dehydrated products.

Their concentrated form, low cost, and convenient and easy transportability made dried products very popular among the armed forces.

Sun-Drying

Sun drying is practiced in tropical and sub-tropical regions where there is plenty of sunshine and almost no rain during the drying season. The equipment consist essentially of drying trays and few other items like knives, lye-bath, etc. Most of the work is done in a drying yard which is kept free from dust, flies, bus etc.

Packing and Storage

The dried products should be put into confectionary tins and sealed air-tight with tin or wax depending upon the length of the period of storage. Dried fruits and vegetables are subject to insect attack even when they have been properly dried and stored.

Sulphuring and Sulphitation

In order to obtain good results during drying and storage. Fruits are given sulphuring treatment before and sometimes after drying. In case of vegetables they are dipped in a solution of KMS (Potassium Meta bisulphite 0.1 to 0.5%) after blanching and then they are dried. This treatment will help in preventing non-enzymatic browning during storage.

Objectives

After going through this experiment, you should be able to:

- know the process of drying of fruits and vegetables; and
- demonstrate the computation of moisture content, drying rates, rehydration ratio.

5.2 EXPERIMENT

5.2.1 Principle

A sample of 'X' mass is dried to the final 'Y' mass in a period of T time.

Amount of moisture loss = X – Y

Percent moisture loss = 100 ((X – Y)/ X)
(wet basis)

Percent moisture loss = 100 ((X – Y) / Y)
(dry basis)

Rate of drying = (X – Y) /T

Dehydrated vegetables need to be rehydrated for consumption. The process of dehydration that results into highest rehydration in considered to be the best.

Rehydration ration = B/A

Where, B is the drained weight of the rehydrated sample. The initial weight of the sample is A.

5.2.2 Requirements

- Selected fruits and vegetable
- Knife
- Cutting board
- Water for washing
- Peeler
- Dry and wet bulb thermo meter
- Perforated drying trays
- Desiccators
- Petri dishes
- Weighing balance (Top pan, digital)
    - 100 g cap., 10 mg. Least Count
    - 5 kg cap., 1g least count

- Hot air oven with temperature control in the range of 50 C – 200 C.
- Selected dryers/ drying environments

5.2.3 Procedure

The steps for moisture content determination, drying experiment and rehydration experiment are being given below.

I) Moisture content determination

- Wash the fruit/vegetable and pat dry to remove surface moisture.
- Cut the fruit/vegetable into small pieces of desired size (**IS- 1708, 1734, 4332**).
- Weigh a sample of about 10 gm in a clean and dry Petri dish. (let the initial weight be X g).
- Heat the oven to the desired temperate and place the sample of fruit/vegetable for the desired time.
- Remove the sample after the desired time from the oven and place it in a desiccator till it cools down to room temperature.
- Weigh the dried sample (Let the final weight be 'Y' g).

II) Drying experiment

- Wash the fruit/vegetable to remove dust and other adhering objects. Remove surface moisture by pat drying or air jet drying.
- Cut the fruit/vegetable into small pieces of desired size using knife and cutting board.
- Spread the cut fruit/vegetable in the drying tray in a thin uniform layer.
- Note the initial weight of the tray with and without the fruit/vegetable sample.
- Place the tray in the selected drying environment (dryer).
- Weigh the tray periodically (1/6, ¼, 1/3, ½ hr, etc.) till the tray weight becomes constant.
- Note the final weight of the tray with dried fruit/vegetable.

III) Rehydration experiment

In rehydration, water is added to the product which is restored to a condition similar to that when it was fresh. The following rehydration test is used to find out the quality of the dried products.

Rehydration test

- Weigh out a sample of 35 grams from the dehydrated product.
- Put the sample into a small container (beaker) and add 275 ml of cold water (and 3.5 g salt).
- Cover the container (with a watch-glass) and bring the water to the boil.
- Boil gently for 30 minutes.

- Turn out the sample onto a white dish.
- At least two people should then examine the sample for palatability, toughness, flavour and presence or absence of bad flavours. The testers should record their results independently.
- The liquid left in the container should be examined for traces of sand/soil and other foreign matter.

Rehydration ratio

If the weight of the dehydrated sample (A) used for the test is 35g and the drained weight of the rehydrated sample (B) 210g, then

$$\text{Rehydration ratio} = \frac{B}{A} = \frac{210}{35} = 6:1$$

5.2.4 Observations

i) Moisture content determination

Weight of Petri dish. = a g.

Initial weight of Petri dish and sample = X g.

Final weight of Petri dish and sample = Y g.

ii) Drying rate

Weight of empty tray = a kg.

Initial weight of tray and the fruit/vegetable sample = X kg.

Periodic weight of tray and the fruit /vegetable sample = Y_i kg.

i = 1,2,3,4 time intervals

Final weight of the tray & the fruit/Vegetable = Y_f kg

Time duration of final drying = T hours.

Table 5.1: Observations for drying experiment

Sl. No.	Time	X	X–a	Drying rate (wet basis)
1.	0.0	X_0	X_0–a	$(X_0 - X_{DT}) / DT$
2.	DT	X_{DT}	X_{DT}–a	$(X_{DT} - X_{2DT}) / DT$
3.	2DT	X_{2DT}	X_{2DT}–a	–
4.	–	–	–	–
5.	T-DT	$X_{(n-2)DT}$	$X_{(n-2)DT}$ –a	–
6.	T	Y	Y–a	$(X_{(n-2)DT} - Y) / DT$

iii) Rehydration

Initial weight of sample to be rehydrated = A g

Final weight of the drained rehydrated sample = B g

5.2.5 Results

1. Moisture Content Determination.

   Moisture content (wet basis) = $((X-Y)/ (X-a)) \times 100$

   Moisture content (dry basis) = $((X-Y) / (Y-a)) \times 100$

2. Drying Rate

   Instantaneous drying rate is computated as given in column 5 of Table 5.1.

   Final drying rate = $(X-Y)/T$ kg/hr.

3. The rehydration ratio can be calculated as the ratio B/A

5.3 PRECAUTIONS

- All measurements of a type should be done uniformly and recorded to the same decimal point. For example, if temperatures are being measured to one decimal point, all values should be recorded to one decimal point only.
- All instruments used in the practical should be properly calibrated.
- The oven needs to be preheated to the desired temperature before the sample is put into it for moisture content determination.
- Petri dishes should be handled gently to avoid any spillage or breakage.
- The computed values need to be rounded off to just one more decimal point than that used for measurement.

EXPERIMENT 6 REPAIR AND MAINTENANCE OF MACHINES

Structure

6.1 INTRODUCTION

Good maintenance and repair procedures contribute significantly to the safety of the maintenance crew as well as that of machine operators and a reduction in the cost of production. Training and aptitude of people assigned to these jobs should make them alert for the intermittent electrical failure, the worn part, the inappropriate noise, the cracks or other signs that warn of impending breakage or that a safeguard has been damaged, altered, or removed. Sometimes all that is needed to keep things running smoothly and safely is machine lubrication or adjustment. Any damage observed or suspected should be reported to the supervisor; if the condition impairs safe operation, the machine should be out of service for repair. Safeguards that are missing, altered, or damaged also should be reported so appropriate action can be taken to insure against worker injury.

Objectives

After studying and performing these experiments, you should be able to:

- know the basic understanding of factory using the available energy utilities with emphasis on up-keep, safety and economy, organisation of the maintenance department; the staff; duties and responsibilities;
- impress upon the workers and managers in a food processing facility that prevention is better than cure;
- ascertain the practices of regular maintenance schedule along with record keeping have been introduced;
- highlight human and equipment safety concerns; and
- explain maintenance of an inventory of critical components is essential to avoid long down times.

6.2 EXPERIMENT

6.2.1 Principle

Machinery breakdowns are always costly. We must strive to avoid the breakdowns through preventive measures.

- Read the operator's manual and ensure proper installation and suggested periodic inspections.
- Maintain regular and complete schedule for greasing and lubrication.
- Ensure proper electrical connections and clean away dust and dirt in areas where connectors are located. Use compressed air instead of water to keep moisture away from the wires.
- Use the machine at its maximum performance level but not beyond it.
- Replace worn parts, and not just broken parts, to avoid frequent break-downs.
- Check for any misalignments and fix them.
- Proper storage of the machine when it is not in use by adequate cleaning and covering.
- Avoid high humidity or condensing environment during machine operation.
- Do not ignore warning signals such as low hydraulic pressure or if a shaft isn't turning on. The warning signals from the digital and analog displays must be taken seriously. Some operators not only ignore the signals but disconnect them completely to stop the signal from beeping or flashing. This too can result in breakdowns. Signals commonly disconnected include those for engine temperature, hydraulic oil, shaft speeds, or other parts that might not be turning at the correct speed.
- Provide adequate training to the machine operator (s).

6.2.2 Requirements

General hand tools required for the maintenance are as follows:

1. Set of open-ended spanners double ended.
2. Set of bihexagon ring spanners double ended.
3. Set of box/ tubular spanners.
4. Set of socket with extension and ratchet.
5. Set of screwdrivers regular and engineering pattern.
6. Set of allen key wrenches.
7. Set of pliers- combination, nose, circlip, adjustable, radio etc.
8. Set of punches.
9. Set of chisels.
10. Set of hammers.
11. Set of G-clamps.
12. Special tools, pullers etc.
13. Grease and oil guns.

6.2.3 Procedure

Daily maintenance

1. Cleaning of the machine so that there is no dirt or any other foreign material in the machine. The machine should usually be clean after the operation is over or after the day work is over. The cleaning operation should not be left over to the next working day. The cotton waste, cloth,

compressed air etc. may be used for cleaning of the processing machines and equipment.

2. Before switching on the machine inspect it externally and carry out the greasing and oiling as per manufacturers recommendation.

3. Check all the nuts and bolts and tighten them if required.

4. Check the belt tensions and adjust if required.

5. Switch on the machine and let it run idle for 5 minutes and observe the machine sound or noise. In case there is some unusual noise, identify it and take appropriate steps for repairs.

Weekly maintenance

In addition to daily maintenance check the oil levels of the various chambers and top them to required levels. Be sure that the recommended oil is used for topping the chambers.

Monthly maintenance

In addition to daily and weekly maintenance, drain the oil from the chambers, clean the chambers and refilled the oil. If the oil change is required may be done according to manufactures recommendations.

Yearly maintenance

1. In addition to daily, weekly and monthly maintenance, the cleaning of bearings and repacking of the grease may be done according to the manufacturers' recommendations.

2. The worn out nut and bolts may be replaced.

3. The belts checked and replaced if required.

4. Changing of the oil according to manufacturers recommendations. Cleaning of oil filters and replacing them if required.

5. Checking of the alignment of the machine and its adjustment if required.

6. Carrying out small repairs or replacement of worn out parts if required.

7. Carrying out all the maintenance as per manufacturers recommendations

6.2.4 Observations

It is recommended to mount a service record chart for each machine on the wall of the work area, with 10-, 50-, 100-, 250- and 500-hour maintenance intervals indicated so they can be performed regularly and the hours marked down. Recommended maintenance operations listed in the operator's manual should be attached to the chart to help operators do all required maintenance procedures.

Also useful is a large planning calendar with machine operating manuals stuck in pockets or hung in a vertical row on the left and columns for each of the months of the year to the right. Use this calendar for noting major repair and service operations to be carried out on each piece of machinery in the months.

Given below is a sample of weekly maintenance chart. Such record not only ensures daily compliance of the inspection/ maintenance work, it becomes a valuable record of the machine performance history.

Table 6.1: Weekly maintenance chart (Machine No.), Week No.
(Tick √ against the activity performed for the day)

Sl. No.	Activity	Mon	Tue	Wed	Thur	Fri	Sat	Sun
1.	Cleaning of the machine							
2.	External inspection before switching the machine							
3.	Greasing/ oiling as per manufacturer's instructions							
4.	Check all the nuts and bolts and tighten them if required							
5.	Check the belt tensions and adjust if required							
6.	Switch on the machine and let it run idle for 5 minutes and observe the machine sound or noise							
7.	check the oil levels of the various chambers and top them to required levels (**weekly**)							
	Remarks							
	Signatures: Operator							
	Signatures: Supervisor							

A suggested service chart to be maintained in the office of the supervisor is given below:

Suggested Service Schedule Format

Service Schedule for ______________________________

Hours of Operation	HOUR METER READINGS																			
10 Hour Service																				
10 Hour Service																				
10 Hour Service																				
10 Hour Service																				
10 Hour Service																				
50 Hour Service																				
100 Hour Service																				
250 Hour Service																				
500 Hour Service																				
1000 Hour or Yearly																				

Place chart in a prominent place in the shop. Perform the required service and write down the hour meter reading. Continue down the column to the 50 hour level and move to the top of the next column after the next 10 hour interval.

6.3 PRECAUTIONS

- As a rule of thumb, spend one to two days in the slack season servicing equipment to avoid breakdowns during the service.
- Before attempting any maintenance, disconnect and lock out the machine from all of its power sources, whether the source is electrical, mechanical, pneumatic, hydraulic, or a combination of these.
- Energy accumulation devices must be "bled down." Open the circuit at the switch box and lock the switch in the "off" position.
- Notifying all affected employees (usually machine or equipment operators or users) that the machine or equipment must be shut down to perform some maintenance or servicing.
- Verifying that the machine or equipment is isolated from the energy source.
- When the servicing or maintenance is completed, inspect the machine or equipment to ensure that all guards and other safety devices are in place and functional,
- Check the area to ensure that energization and start up of the machine or equipment will not endanger employees.

- Remove the lockout devices.
- Re-energize the machine or equipment, and notify affected employees that the machine or equipment may be returned to service.
- All the right tools should be on hand and in good repair.
- Lubricating oils and other common supplies should be readily available and safely stored.
- Commonly used machine parts and hardware should be kept in stock.

ANNEXURE I

Vinegar

The name 'Vinegar' is derived from Latin word Vine-gry means wine-sour. The name itself indicates that vinegar is prepared by fermenting of wine into vinegar or alcohol into acetic acid, because during fermentation Alcohol is converted by micro-organism into acetic acid. Generally vinegar contain 4% Acetic Acid. Vinegar can be calssified into four groups according to the source of materials namely:

1. Synthetic Vinegar
2. Brewed Vinegar (Malt)
3. Spirit Vinegar
4. Distilled Vinegar

1. ***Synthetic Vinegar:*** Is self explanatory. It is prepared by diluting glacial acetic acid to 4% and colouring with suitable colour (caramel) to give appearance like brewed vinegar or natural fermented vinegar. According to FPO it must contain 4% acetic acid.

   Preparation: a) Boil water, strain and allow it to cool, b) Add acetic acid at the rate of 50ml/1Litre of water, c) Fill in bottles, cork, label and store. A little caramel colour is added to improve colour and flavour.

2. ***Brewed Vinegar:*** Is prepared by fermenting and food material which contain sugar into alcohol and from alcohol into vinegar by natural process of fermentation. It must contain minimum 3.75% acetic acid weight/volume.

3. ***Spirit – Vinegar:*** When vinegar is prepared directly from alcohol without any sugar, it is known as spirit vinegar. The source of alcohol could be any sugary material. It must also have 3.75% acetic acid.

4. ***Distilled Vinegar:*** It is colourless vinegar prepared by distilling any brewed or spirit vinegar. It must also contain 3.75% acetic acid weight/volume.

   It is easy to differentiate all the types of vinegar by analysis. Synthetic vinegar does not have any other volatile substance than acetic acid. While other three types of vinegar have volatile other than acetic acid in varying degree and from this one can easily find out whether vinegar has prepared synthetically, fermentation or distillation.

   In preparing vinegar any food containing appreciate quantity of sugar e.g. fruits and vegetables waste, dried fruits honey etc. can be used.

ANNEXURE II

Boiling Temperatures

Juice, sugar mixtures (Jam Boiling Temperature)

Boiling Point			
	Percentage sugar	At sea level	500' Above sea level
	50	216	215.2
	52	216.6	215.8
	54	217	216.2
	56	217.15	216.7
	58	218.1	217.3
	60	218.7	217.9
	62	219.4	218.6
	64	220.2	219.4
	66	221.2	220.1
Jam, Jellying Temperature	68	222.2	221.4
	70	223.5	222.7
	72	225.0	224.2
	74	226.8	226
Toffee Setting Temperature	76	229.1	228.3

Approximate Conversion of Measure

1 Tea spoon	= 5 ml
1 Table spoon	= 15 ml (3 tea spoon)
1 Oz	= 2 table spoons = 30 ml
1 Cup	= 8 oz = 230 ml
1 Soda Bottle	= 7 oz = 200 ml
1 Ketchup Bottle	= 12 oz = 350 mls
1 Sugar Bottle (big)	= 24 oz = 720 mls
1 Pint	= 568 mls
1 Litre	= 1000 mls = 7½ cups

UNIT 1 CLASSIFICATION OF MICROORGANISMS IMPORTANT IN THE FOOD INDUSTRY: BACTERIA, YEASTS AND MOLD

Structure

1.0 OBJECTIVES

The objectives of this unit are to enable you to understand the important genera of microorganisms associated with food. This unit gives a brief account of the morphological, physiological and cultural characteristics of various microorganisms. After going through this unit, you should be able to:

- know the various types of microorganisms;
- explain the requirements for their growth;
- learn the classification of these organisms based on their characteristics; and
- distinguish between the useful and harmful microorganisms.

1.1 INTRODUCTION

We already know that the microorganisms use our food as a source of nutrients for their own growth. This, of course can result in deterioration of the food. By increasing their numbers, utilizing nutrients, producing enzymatic changes and contributing off flavors by means of breakdown of a product or synthesis of new compounds they can "spoil" a food. When the microorganisms involved are pathogenic, their association with our food supply is critical from a public health point of view. Therefore a classification of different organisms and their growth requirements is required to prevent spoilage of foods.

1.2 VARIOUS TYPES OF MICROORGANISMS

Microbes are single-cell organisms so tiny that millions can fit into the eye of a needle. They are the oldest form of life on earth. Microbe fossils date back more than 3.5 billion years to a time when the Earth was covered with oceans that regularly reached the boiling point, hundreds of millions of years before dinosaurs roamed the earth. Without microbes, we couldn't eat or breathe. Without us, they'd probably be just fine.

Bacteria

Many of us know bacteria only as "germs," invisible to naked eyes that can invade our bodies and make us sick. Few know that many bacteria not only coexist with us all the time, but help us do an amazing array of useful things like make vitamins, break down garbage, and even maintain our atmosphere. These are unicellular microorganisms that are classed as plants. A bacterial cell is about 1µm in length and somewhat smaller in diameter. Bacteria are classified according to their shape. Cocci are spherical, bacilli are cylindrical and spirilla and vibrios are spiral. Bacterial spores are more heat resistant than yeast or mold spores to most processing conditions. Bacteria, with a few exceptions cannot grow in acid media in which yeasts and molds thrive. They multiply by 'binary fission'. When a bacterium becomes mature it divides into two, these two become four and so on. Bacteria can be found virtually everywhere. They are in the air, the soil, and water, and in and on plants and animals, including us. A single teaspoon of topsoil contains about a billion bacterial cells (and about 120,000 fungal cells and some 25,000 algal cells). The human mouth is home to more than 500 species of bacteria. Some bacteria (along with archaea) thrive in the most forbidding, uninviting places on Earth, from nearly-boiling hot springs to super-chilled Antarctic lakes buried under sheets of ice. Microbes that dwell in these extreme habitats are aptly called extremophiles. The growth of bacteria is very rapid and depends upon the nature of the food material, moisture, temperature and air. Some bacteria do not grow in air but temperature plays a major role in their growth, the optimum being generally 37°C for bacteria pathogenic to humans.

Bacteria are very sensitive to acids and are destroyed in their presence even at temperature of boiling water. Hence, most fruits being acidic can be easily sterilized at 100°C whereas vegetables being non-acidic require a higher temperature of 116°C.

A bacterium's genetic information is contained in a single DNA molecule suspended in a jelly-like substance called cytoplasm. In most cases, this and other cell parts are surrounded by a flexible cytoplasmic membrane that is itself surrounded by a tough, rigid cell wall. A few species, such as the mycoplasmas, don't have cell walls.

Even though bacteria have only one cell each, they come in a wide range of shapes, sizes, and colours.

The important groups of bacteria are:

a) Bacillus: rod-shaped.

b) Coccus: spherical.

c) Coccobacillus: oval-shaped.

d) Aerobes: require atmospheric oxygen for growth, e.g., *Acetobacter aceti*.

e) Facultative anaerobes: can grow with or without atmospheric oxygen.

f) Obligate anaerobes: do not grow in atmospheric oxygen.

g) Mesophiles: require a temperature below 38°C for growth.

h) Obligate thermophiles: grow between 38°C and 82°C.

i) Facultative thermophiles: grow over a wide range of temperatures covered by mesophiles and obligate thermophiles and below.

j) Psychrotrophs: grow fairly well at refrigeration temperatures and some can even grow slowly at temperatures below freezing.

Some bacteria have natural colours. Certain species contain pigments, such as various chlorophylls, that make them naturally green, yellow, orange, or brown. Colonies of millions of bacteria may appear pink, yellowish, or white.

Important Food Spoilage Bacteria

Group	Genus
Acetics	*Acetobacter* and *Gluconobacter*
Lactics	*Lactobacillus, Leuconostoc, Pediococuus, Sreptococcus*
Butyrics	*Clostridium*
Propionics	*Propionibacterium*
Proteolytics	*Bacillus, Pseudomonas, Closridium, Proteus etc.*

Some useful bacteria

The following bacteria are of great importance in the food processing industry.

Acetobacter sp.

These bacteria, also known as "vinegar bacteria", cause significant spoilage in the wine industry but are necessary for vinegar production. The important species are *Acetobacter aceti, A. orleansis and A.schutzenbachi*. They are very small, usually non-motile and generally do not form spores. These bacteria are aerobes and in the presence of oxygen convert ethyl alcohol to acetic acid. These bacteria can be easily destroyed by heating to 65°C.

Lactobacillus sp.

Different organisms of this group, also known as "lactic acid bacteria", have different properties but all of them produce lactic acid from carbohydrates. The important species include *Lactobacillus plantarum, Pediococcus cerevisiae, Leuconostoc mesenteroides, Streptococcus faecalis* and *Lactobacillus brevis.* These bacteria cause "lactic souring" and spoil wines, which can be easily prevented by maintaining a sulphur dioxide concentration of 0.007 per cent in wine.

Yeasts

Yeasts are unicellular fungi which are widely distributed in nature. They are somewhat larger than bacteria. The cell length is about 10µm and the diameter is about a third of this. Most yeasts are spherical or ellipsoidal. Yeasts that multiply by means of 'budding' are known as 'true yeasts'. Yeasts grow luxuriously at a moderate temperature in a solution of sugar in plenty of water.

Under suitable conditions the sugar is converted into alcohol and carbon dioxide is evolved. This is the reason that carbon dioxide is evolved from food materials spoiled by yeasts and pushes out corks from bottles with great force. Most of them do not develop in media containing more than 66% sugar or 0.5% acetic acid. Boiling destroys the yeast cells and spores completely. Some of the yeasts which grow on fruits are *Saccharomyces, Candida* and *Brettanomyces.*

Pseudo-yeasts

These are like true yeasts but do not form spores. All the members of this group are particularly unsuitable for fermentation purposes as they produce off-flavours and cloudiness.

Yeasts causing food spoilage

Yeast	Product Spoilage
Saccharomyces	Low sugar products
Candida	High-acid foods, salty foods, butter
Brettanomyces	Beers, wines
Zygosaccharomyces (osmophillic)	Honey, syrups, molasses, wines, soy sauce
Pichia	Wines
Hansenula	Beers
Torulopsis	Milk products, fruit juices, acid foods
Rhodotorula	Meat, sauerkraut

Fungi (Molds)

Fungi are eukaryotic organisms. This means that their DNA-containing chromosomes are enclosed within a nucleus inside their cells. (The chromosomes of bacteria and archaea are not walled off inside nuclei, making them prokaryotic organisms). Molds are multicellular, filamentous fungi which are devoid of chlorophyll. They are larger than yeasts. They are strict aerobes and require oxygen for growth and multiplication and tend to grow more slowly than bacteria.

Fungi are lower thallophytic plants but do not make their own food via photosynthesis like green plants. They feed on organic matter like rotting leaves, wood, and other debris, or upon the tissues of living plants and animals.

Fungi, along with bacteria, are the planet's major composters and recyclers. Although fungi may seem like a nuisance when they grow in your fruit bowl or refrigerator, their ability to degrade some of the toughest organic materials, including tree wood and insect exoskeletons, means that our planet is not cluttered with a mass of debris. Fungi secrete digestive enzymes in order to break down complex food sources, such as animal corpses and tree stumps, into smaller components they can absorb.

The principle parts of a mold are a web-like structure known as mycelium and the spore. The mycelium is often white and cottony and penetrates into the attacked foodstuff. After fixing itself the mold produces viable spores which resist the favourable conditions after the dispersal and germinate when they get favourable conditions. They thrive best in closed, damp and dark situations with an adequate supply or warm, moist air but require less free moisture than yeasts and bacteria. They prefer sugar containing substances and may spoil jams, jellies and other sugar-based products. Acid medium favours their growth and, therefore, they grow well in pickles, juices etc. this is the main reason that fruit and fruit products are attacked by molds which not only consume nutrients present in the food thereby lowering its food value but also spoil the flavour, texture and appearance of the product. Molds are sensitive to heat; boiling quickly destroys molds and their spores. The most important molds are:

a) *Penicillium* sp. (Blue moulds)
b) *Aspergillus* sp. (Black moulds)
c) *Mucor* sp. (Gray moulds)
d) *Bysslchlamyces fulva*

Classification of Microorganisms

A) On basis of temperature for growth

Microorganisms can be classified into:

– Thermophillic: Microbes who require high temperature for their growth and survival (optimum temperature=45-65ºC).

– Thermoduric: Microbes which do not grow at high temperatures but can survive in it.

– Mesophillic: Microorganisms which require optimum temperature of 20-50ºC for growth and multiplication.

– Psychrophillic: Microorganisms requiring less than 20ºC as optimal temperature for growth.

– Psychroduric: Microorganisms which do not grow at low temperature but can survive.

B) On basis of oxygen requirement for growth:

– Obligate Aerobes: Require oxygen for growth and multiplication e.g. molds.

– Obligate Anaerobes: Strictly grow only in absence of oxygen.

– Facultative: Microorganisms than can grow in both presence and absence of oxygen e.g. yeasts.

– Microaerophillic: Organisms which are able to grow at very low oxidation-reduction potential.

C) On basis of requirement of water activity.

In general, bacteria require more moisture than yeasts and yeasts more than molds.

The classification according to requirement of a_w is as follows:

Group of microorganism	Minimal a_w value
Bacteria	0.91
Yeast	0.88
Molds	0.80
Halophillic bacteria	0.75
Xerophillic fungi	0.65
Osmophillic Yeasts	0.60

- Halophillic bacteria: Bacteria which grow in high salt solutions
- Osmophillic Yeasts: Yeasts which can grow best in high concentrations of sugar
- Xerophillic Fungi: Fungi which can grow in low water activity

D) On basis of nutrient degradation capacity:

- Proteolytic: Microorganisms which are capable of protein degradation because of extracellular proteinases produced.
- Lipolytic: Microbes which catalyxe the hydrolysis of fats to fatty acids and glycerol.
- Sacchrolytic: These microorganisms hydrolyse disaccharides or polysaccharides to simpler sugars.
- Pectinolytic: These microorganisms hydrolyse pectin.

E) On basis of staining:

On basis of staining the bacteria can be classified as:

- Gram positive: Those bacteria that stain violet after Gram stain test. In these the cell wall is mostly comprised of peptidoglycan layer.
- Gram negative: Those bacteria that do not stain violet after Gram stain test. Cell wall mainly comprised of lipopolysaccharides.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Classify bacteria according to their morphology.

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2. Differentiate between yeasts and molds.

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3. Classify microorganisms on basis of the temperature requirements, oxygen requirements, water activity requirement, staining procedure and nutrient degrading capability.

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1.3 CHARACTERISTICS (MORPHOLOGICAL, CULTURAL AND PHYSIOLOGICAL) OF MICROORGANISMS

1.3.1 Bacteria

Morphological Characteristics

One of the first step in the identification of bacteria in food is microscopic examination to ascertain the shape, size, aggregation, structure and staining reactions of the bacteria present. The following characteristics may be of special significance:

Encapsulation: The presence of capsules or slime may account for sliminess or ropiness of a food. Most capsules are polysaccharides of dextrin, dextran or levan and they serve as a source of reserve nutrients and increase the resistance of bacteria under adverse conditions.

Formation of Endospores: Bacteria of genera *Bacillus, Clostridium, Sporosarcina* etc have the ability to form endospores. Endospores are formed at an intracellular site and are resistant to heat, ultraviolet light and dessication. Lysis of the vegetative cell releases the free endospore, which may remain dormant with no detectable metabolism for years. Sporulation usually appears in the late logarithmic phase of growth, possibly because of nutrient depletion or product accumulation. The acquisition of heat resistance is closely related to the formation of dipicolinic acid and the Ca^{2+} uptake. Germination is favoured by conditions that are favourable for growth.

Formation of Cell Aggregates: It is characteristic of some bacteria to form long chains or of others to clump under certain conditions. It is more difficult to kill all bacteria in intertwined chains or sizable clumps than to destroy separate cells.

Cultural Characteristics

Bacterial growth in and on foods often is extensive enough to make the food unattractive in appearance or otherwise objectionable. Pigmented bacteria cause discolouration on the surfaces of foods; films which may cover the surfaces of liquids; growth may make surfaces slimy; or growth throughout the liquids may result in undesirable cloudiness or sediment.

Physiological Characteristics

Most bacteria may be placed into one of three groups based on their response to gaseous oxygen. Aerobic bacteria thrive in the presence of oxygen and require it for their continued growth and existence. Other bacteria are anaerobic, and cannot tolerate gaseous oxygen, such as those bacteria which live in deep underwater sediments, or those which cause bacterial food poisoning. The third group are the facultative anaerobes, which prefer growing in the presence of oxygen, but can continue to grow without it.

Bacteria may also be classified both by the mode by which they obtain their energy. Classified by the source of their energy, bacteria fall into two categories: heterotrophs and autotrophs. Heterotrophs derive energy from breaking down complex organic compounds that they must take in from the environment – this includes saprobic bacteria found in decaying material, as well as those that rely on fermentation or respiration.

The other group, the autotrophs, fix carbon dioxide to make their own food source; this may be fueled by light energy (photoautotrophic), or by oxidation of nitrogen, sulfur, or other elements (chemoautotrophic). While chemoautotrophs are uncommon, photoautotrophs are common and quite diverse. They include the cyanobacteria, green sulfur bacteria, purple sulfur bacteria, and purple nonsulfur bacteria. The sulfur bacteria are particularly interesting, since they use hydrogen sulfide as hydrogen donor, instead of water like most other photosynthetic organisms, including cyanobacteria.

Microbe is a term for tiny creatures that individually are too small to be seen with the unaided eye. Microbes include bacteria (*back-tear-ee-uh*), archaea (*are-key-uh*), fungi (*fun-jeye*) and protists (*pro-tists*). You've probably heard of bacteria and fungi before. Archaea are bacteria-like creatures that have some traits not found in any true bacteria. Protists include primitive algae (*al-gee*), amoebas (*ah-me-buhs*), slime molds and protozoa (*pro-toe-zoh-uh*). We can also include viruses (*vye-rus-is*) as a major type of microbe, though there is a debate as to whether viruses can be considered living creatures or not.

1.3.2 Molds

General Characteristics

The term "mold" is a common one applied to certain multicellular, filamentous fungi whose growth on foods usually is readily recognized by its fuzzy or cottony appearance. The main part of the growth commonly appears white but may be coloured or dark or smoky. Coloured spores are typical of mature mold of some kinds and give colour to part or all of the growth. The thallus, or vegetative body, is characteristic of thallophytes, which lack true roots, stems and leaves.

Morpohological Chactacteristics

The morphology, i.e. the form and structure, of molds, as judged by their macroscopic and microscopic appearance, is used in their identification and classification.

Hyphae and Mycelium: The mold thallus consists of a mass of branched, intertwined filaments called hyphae (singular hypha), and the whole mass of these hyphae are known as the mycelium.

Reproductive Parts or Structures: Molds can grow from a transplanted piece of mycelium. Reproduction of molds is chiefly by means of asexual spores. Some molds also form sexual spores.

Culture Characteristics

The gross appearance of a mold growing on a food often is sufficient to indicate its class or order. Some molds are loose and fluffy; others are compact. Some look velvety on the upper surface, some dry and powdery, and others wet or gelatinous. Some molds are restricted in size, while others seem limited only by the food or container. Pigments in the mycelium – red, purple, yellow, brown, gray black, etc. – are characteristic, as are the pigments of mass of asexual spores; green, blue-green, yellow, orange, pink, lavender, brown, gray, black, etc.

Physiological Characteristics

The physiological characteristics of molds will be reviewed only briefly here and will be discussed in more detail subsequently.

Moisture Requirements: In general most molds require less available moisture than do most yeasts and bacteria. It has been claimed that below 14 to 15 percent total moisture in flour or some dried fruits will prevent or greatly delay mold growth.

Temperature Requirements: Most molds would be considered mesophilic i.e. able to grow well at ordinary temperature. The optimal temperature for most molds is around 25 to 30°C, but some grow well at 35 to 37°C or above, e.g. *Aspergillus* spp. And some at still higher temperatures. A number of molds are psychrotophic or psychroduric i.e. they grow fairly well at temperatures of refrigeration, and some can grow slowly at temperatures below freezing. Growth has been reported at as low as – 5 to 10°C. A few are thermophilic; i.e. they have a high optimal temperature.

Oxygen and pH Requirements Molds are aerobic; i.e. they require oxygen for growth; this is true at least for the molds growing on foods. Most molds can grow over a wide range of hydrogen-ion concentration (pH 2 to 8.5), but the majority are favoured by an acid pH.

Food Requirements: Molds in general can utilize many kinds of foods, ranging from simple to complex. Most of the common molds possess a variety of hydrolytic enzymes, and some are grown for their amylases, pectinases, proteinases, and lipases.

Inhibitors: Compounds inhibitory to other organisms are produced by some molds, such as penicillin from *Penicillium chrysogenum* and clavacin from *Aspergillus clavatus.* Certain chemical compounds are mycostatic, inhibiting the growth of molds (sorbic acid, propionates, and acetates are examples), or are specifically fungicidal, killing molds.

Initiation of growth of molds is slow compared to that of bacteria or yeasts, so that when conditions are favourable for all these organisms, molds usually lose out in the competition. After mold growth is under way, however, it may be very rapid.

1.3.3 Yeasts

Like mold, the term "yeast" is commonly used but hard to define. As used here it refers to those fungi which are generally not filamentous but unicellular and ovoid or spheroid and which reproduce by budding or fission.

Yeasts may be useful or harmful in foods. Yeast fermentations are involved in the manufacture of foods such as bread, beer, wines, vinegar, and surface-ripened cheese, and yeasts are grown for enzymes and for food. Yeasts are undesirable when they cause spoilage of sauerkraut, fruit juices, syrups, molasses, honey, jellies, meats, wine, beer, and other foods.

Morphological Characteristics

Form and structure: The form of yeasts may be spherical to ovoid, lemon-shaped, pear-shaped, cylindrical, triangular, or even elongated into a false or true mycelium. They also differ in size.

Reproduction: Most yeasts reproduce asexually by multilateral or polar budding, a process in which some of the protoplasm bulges out the cell wall; the bulge grows in size and finally walls off as a new yeast cell. A new species or yeasts reproduce by fission, and one reproduces by combination of fission and budding.

Sexual reproduction of "true" yeasts *(Ascomycotina)* results in the production of ascospores, the yeast cell serving as the ascus. The ascospores may differ in colour, in smoothness or roughness of their walls, and in their shape (round, oval, reniform, bean or sickle-shaped, hemispherical, angular, fusiform, or needle-shaped).

"False" yeasts, which produce no ascospores or other sexual spores, belong to the *Fungi Imperfecti.* Cells of some yeasts become chlamydospores by formation of a thick wall about the cell, for example, *Candida, Rhodotorula, and Cryptococcus.*

Cultural Characteristics

For the most part, the appearance of massed yeast growth is not useful in the identification of yeasts, although growth as a film on the surface of liquid media suggests an oxidative or film yeasts, and production of a carotenoids pigment indicates the genus *Rhodotorula.* However, the appearance of the growth is important when it causes coloured spots on foods.

Yeasts are oxidative, fermentative, or both. The oxidative yeasts may grow as a film, pellicle, or scum on the surface of liquid and then are termed *film yeasts.* Fermentative yeasts usually grow throughout the liquid and produce carbon dioxide.

Physiological Characteristics

Most common yeasts grow best with a plentiful supply of available moisture. But since many yeasts grow in the presence of greater concentration of solutes (such as sugar or salt) than most bacteria it can be concluded that these yeasts require less moisture than the majority of bacteria. Most yeast require more moisture than molds, however, on the basis of water activity or aw yeasts may be classified as ordinary if they do not grow in high concentrations of solutes, i.e. in a low aw, and as osmophilic if they do. However limits of aw for ordinary yeasts tested thus far ranges from 0.88 to 0.94.

The range of temperature for growth of most yeasts is, in general, similar to that for molds, with the optimum around 25°C to 30°C and the maximum about 35°C to 47°C. Some kinds can grow at 0°C or less. The growth of most yeasts if favoured by an acid reaction in the vicinity of pH 4 to 4.5, and they will not grow well in an alkaline medium unless adapted to it. Yeasts grow best under aerobic conditions, but the fermentative types can grow anaerobically, although slowly.

In general, sugars are the best source of energy for yeasts, although oxidative yeasts, e.g., the film yeasts, oxidize organic acids and alcohol. Carbon dioxide produced by bread yeasts accomplishes the leavening of bread, and alcohol made by the fermentative yeasts is the main product in the manufacture of wines, beer, industrial alcohol, and other products. The yeasts also aid in the production of flavors or "bouquet" in wines.

Nitrogenous foods utilized vary from simple compounds such as ammonia and urea to amino acids and polypeptides. In addition, yeasts require accessory growth factors.

Microorganisms, namely, bacteria, yeasts and molds can be found in any environment. The eight environmental sources of organisms to foods are: soil and water, plants and plant products, food utensils, intestinal tracts of humans and animals, food handlers, animal feeds, animal hides, air and dust. Although we see that the microorganisms are beneficial to the humans in many ways, there are many microorganisms that are the causative agents for food borne diseases. e.g. *Staphlococcus aureus* and *Clostridium botulinum* cause food borne intoxication whereas *Salmonella, E.coli, Campylobacter, Listeria,* *Yersinia, Bacillus* etc cause food borne infections. Molds are responsible for causing food intoxication by production of mycotoxins, which are lethal for the human body e.g. Aflatoxin produced by *Aspergillus flavus*, patulin produced by *Penicillium expansum*, ochratoxins produced by *Aspergillus ochraceus* etc. All these will be discussed in Unit 3.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the formation of special structures by bacteria.

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2. What are the physiological requirements of molds?

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3. Yeasts maybe useful or harmful. Explain.

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1.4 LET US SUM UP

This unit briefly outlines the identification and classification of food microorganisms. After reading this unit, you will be able to classify microorganisms broadly into three categories: bacteria, yeasts and molds. Further you will be able to categorize these microorganisms on the basis of their requirements of temperature, oxygen, water activity for growth and also on the basis of their ability to degrade certain nutrients. To prevent the spoilage of food products, appropriate measures have to be taken for preventing their growth and multiplication. Hence food microbiologists have to be well versed with the various morphological, cultural and physiological characteristics of the different microorganisms so as to prevent their growth and proliferation.

After reading this unit, you will get a knowledge of the factors that favour or inhibit the growth of microorganisms which are essential to give an understanding of the principles of food spoilage and preservation.

1.5 KEY WORDS

Bacteria	:	Unicellular microorganisms 1µm in length, lacking chlorophyll and multiply by binary fission.
Yeasts	:	Unicellular fungi, larger than bacteria, which multiply by budding.
Molds	:	Multicellular, filamentous fungi devoid of chlorophyll.
Endospore	:	Heat resistant structures formed by bacteria under unfavourable conditions (nutrient depletion or product accumulation) which remain dormant till exposed to favourable environment.
Capsule	:	Slimy material composed of polysaccharides that serve as a source of reserve nutrients and make cell resistant to adverse conditions.
Mycostatic	:	Substances which are inhibitory to mold growth.
Fungicidal	:	Substances capable of killing the fungi.
Thermophillic organisms	:	Microorganisms which require high optimum temperature for their growth and multiplication (45-60ºC).
Mesophillic organisms	:	Microorganisms whose optimum temperature for growth is 25-40ºC.
Proteolytic microorganisms	:	Microorganisms that have the capacity to break down complex proteins to amino acids due to production of extracellular protein degrading enzymes.
Gram positive bacteria	:	Bacteria that stain violet after Gram staining.
Gram negative bacteria	:	Bacteria that stain red after Gram staining.

Psychrophillic microorganisms : Microorganisms requiring less than 20ºC as optimal temperature for growth.

Obligate aerobes : Microorganisms that grow and multiply only in presence of oxygen.

Obligate anaerobes : Microorganisms that grow and multiply only in absence of oxygen.

Facultative microorganisms : Those microorganisms that can grow and survive under both aerobic and anaerobic conditions.

Microaerophillic microorganisms : Those microorganisms that can grow and survive under low concentrations of oxygen.

Thermoduric microorganisms : Those microorganisms that can survive at high temperatures but grows in mesophillic range.

1.6 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. On basis of morphology bacteria can be classified as:

   a) Bacilli: rod-shaped

   b) Coccus: spherical

   c) Coccobacillus: oval-shaped

   d) Spirilla: spiral shaped

2. Yeasts are unicellular fungi and are smaller in size whereas molds are multicellular and filamentous and are larger than yeasts. Yeasts multiply asexually by budding whereas molds reproduce sexually by spores. Yeasts can grow in anaerobic conditions but molds are strictly aerobic.

3. Classification of microorganisms on basis of temperature requirement:

   a) Thermophillic(45-60ºC)

   b) Thermoduric

   c) Mesophillic (25-40ºC)

   d) Psychroduric

   e) Psychrophillic

   Classification of microorganisms on basis of oxygen requirement:

   a) Obligate aerobes: Strictly grow in presence of oxygen

   b) Obligate anaerobes: Strictly grow in absence of oxygen

   c) Facultative: Can grow both in presence and absence of oxygen

   d) Microaerophillic: Grow at low oxygen concentrations

Classification of microorganisms on basis of a_w requirement:

a) Bacteria (a_w =0.9)

b) Yeast (0.88)

c) Mold (0.80)

d) Halophillic bacteria (0.75)

e) Xerphillic molds (0.65)

f) Osmophillic yeasts (0.60)

Classification of microorganisms on basis of nutrient degradation:

a) Lipolytic: Fat degrading

b) Saccharolytic: Sugar degrading

c) Pectinolytic: Pectin degrading

d) Proteolytic: Protein degrading

Classification of microorganisms on basis of staining:

a) Gram positive bacteria: Stain violet after staining

b) Gram negative bacteria: Stain red after Gram staining

Check Your Progress Exercise 2

1. Bacteria form special structures such as endospores, capsules and cell aggregates to combat the adverse environmental conditions. Bacteria of genera *Bacillus, Clostridium, Sporosarcina* etc have the ability to form heat resistant endospores. Sporulation usually appears in the late logarithmic phase of growth, possibly because of nutrient depletion or accumulation of toxic products. Endospores may remain dormant with no detectable metabolism for years and germinate when exposed to favourable conditions for growth. Capsules serve as a source of reserve nutrients and increase the resistance of bacteria under adverse conditions. They are composed of dextran and levan and account for sliminess or ropiness of a food. Bacteria may also form aggregates which helps them to combat unfavourable environments.

2. Physiological requirements of molds: Molds are mesophillic and grow well at 25-30°C. Some are psychrotrophic and can grow at –5 to 10°C. They are aerobic in nature and can grow at wide range of pH 2-8.5. They require a minimum moisture range of 14-15 per cent to grow. Owing to a number of hydrolytic enzymes, molds can proliferate on complex media also.

3. Yeasts may be useful or harmful in foods. Yeast fermentations are involved in the manufacture of foods such as bread, beer, wines, vinegar, and surface-ripened cheese, and yeasts are grown for enzymes and for food. Yeasts are undesirable when they cause spoilage of sauerkraut, fruit juices, syrups, molasses, honey, jellies, meats, wine, beer, and other foods.

1.7 SOME USEFUL BOOKS

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UNIT 2 FACTORS AFFECTING GROWTH AND INHIBITION OF MICROORGANISMS IN FOOD

Structure

2.0 OBJECTIVES

After reading this unit you should be able to:

- list out the various factors that favour/inhibit the growth of microorganisms;
- explain the role played by pH in inhibition of microbial growth;
- explain the effect of water activity on microbial growth and activities;
- explain the influence of redox potential on the natural microflora of food and the type of spoilage occurring in food;
- understand the role played by nutrient composition on type of microorganisms growing in food;
- understand the role played by antimicrobial barriers in retarding microbial spoilage of food; and
- understand the role played by inhibitory substances in retarding microbial spoilage of food.

2.1 INTRODUCTION

Microorganisms use our food supply as a source of nutrients and energy. They increase their numbers by utilizing nutrients. This can result in a deterioration of the food. They produce enzymatic changes and off-flavours in food by breaking down a nutrient or synthesizing new compounds. Thus, they "spoil" our food and make it unfit for consumption. To prevent this we reduce the contact between microorganisms and our foods (prevent contamination) and also eliminate microorganisms from our foods, or adjust conditions of storage in such a way that their growth is prevented (preservation) and thus, there is no spoilage of food.

If the microorganisms involved are pathogenic, then their presence in our food will lead to outbreak of food borne diseases also. Many of our foods support the growth of pathogenic microorganisms or serve as a source of them. Here again, we attempt to prevent their entrance and growth in our foods or eliminate them by processing.

Interactions between microorganisms and our foods are also beneficial. Many of the cultured products consumed and enjoyed for example cultured buttermilk, yoghurt, sauerkraut, pickles and tofu are produced as a result of beneficial activities of microorganisms.

Food is the substrate for growth of microorganisms, so the characteristics of a food are important. Food or substrate will determine which microorganisms can or cannot grow on it so there is a need to understand the characteristics of the food or substrate. Then only one can make predictions about the microbial flora that may develop and flourish in it. This microflora will bring about the biochemical changes in food due to their activities. The types of biochemical changes will determine whether those changes are beneficial or harmful.

Knowledge of the factors that favour or inhibit the growth of microorganisms is very important. It will help us in understanding the principles of food spoilage and preservation. The chief compositional factors of food that influence microbial activity are hydrogen-ion concentration, moisture, oxidation-reduction (O-R) potential, nutrients, biological structure and presence of inhibitory substances.

2.2 HYDROGEN-ION CONCENTRATION (pH)

The acidity and alkalinity (pH) of an environment has a strong influence on the activity and stability of macromolecules such as enzymes. These enzymes play an important role during growth of microorganisms and in their metabolism. Thus, growth and metabolism of microorganisms are influenced by pH.

2.2.1 Effect on Microbial Growth

Every microorganism has a minimal, a maximal, and an optimal pH for growth. In general, bacteria grow in the pH range of 6.0–8.0, yeasts 4.5-6.0 and filamentous fungi 3.5-4.0. Molds can grow over a wider range of pH than most yeasts and bacteria, and many molds grow at acidities too high for yeasts and bacteria. Most fermentative yeasts grow well in pH range of about 4.0 to 4.5, eg. fruit juices, and film yeasts grow well on acid foods, such as sauerkraut and pickles. On the other hand, most yeast do not grow well in alkaline foods and thus do not have a significant role to play in the spoilage of food products with high pH. However, large number of yeasts grow well in near neutral pH. There are some exceptions for example some bacteria can grow in moderate acidity particularly those bacteria that produce large acids as a result of their activities like lactobacilli and acetic acid bacteria. These have pH optima between 5.0 and 6.0 and others like the proteolytic bacteria can grow in foods with a high (alkaline) pH, as found in the stored egg white. Bacteria are more sensitive to pH than molds and yeasts, with the pathogenic bacteria being the most sensitive amongst them. The pH values of some of the common foods along with the pH range for growth of some groups of microorganisms and a few of food associated pathogenic bacteria are given in Table 2.1.

Table 2.1: The pH ranges of some common food items and pH range of some common food microflora

Food	pH range	Organism	pH range
Citrus fruits	2-5	Molds	0-11
Soft drinks	2.5-4	Yeasts	1.5-8.5
Beer	3.5-4.5	Lactic acid bacteria	3.2-10.5
Meat	5.5-6.2	*Staphylococcus aureus*	4-9.8
Fish	6.5-7.3	*Salmonella* spp.	4.1-9
Egg white	8.6-9.6	*Escherichia coli*	4.3-9
Milk	6.5-7	*Yersinia enterocolitica*	4.5-9
Flour	6.2-7.2	*Clostridium botulinum*	4.8-8.2
Vegetables	4.8-7	*Clostridium perfringens*	5.4-8.7
Fermented shark	10-12	*Bacillus cereus*	4.7-9.3

pH minima and maxima of microorganisms also varies due to other important factors like temperature, moisture content, salt concentration, redox potential etc. For example, in the presence of 0.2 M NaCl, *Alcaligenes faecalis* can grow over a wider pH range than in the absence of NaCI or in the presence of 0.2 M sodium citrate. The pH minima of certain lactobacilli also depends upon the type of acid used, for example with citric, hydrochloric, phosphoric and tartaric acids growth can occur at lower pH than in presence of acetic or lactic acids. In general, yeast and molds are more acid-tolerant than bacteria.

When microorganisms are grown at pH either higher or lower than their optimum pH there is an increase in lag phase of the microbe. The increased lag would be of longer duration if the food has a good buffering capacity in contrast to one that has poor buffering capacity. Good buffering capacity of food would result in slower change in pH of food due to microbial activity. A respiring microbial cell is adversely affected by pH since it affects the functioning of enzymes and the transport of nutrients into the cell. In addition to the effect of pH on rate of growth of microorganisms, pH also affects rate of survival of microorganisms during storage, heating, drying and other forms of processing. Many times the initial pH may be suitable, but growth of the organism itself may alter the pH, thereby making it unfavourable. Conversely, the initial pH may be restrictive, but the growth of a limited number of microorganisms may alter the pH to a more favourable range for the growth of many other microorganisms.

The inherent pH of foods varies, although most are neutral or acidic. Materials with an alkaline pH generally have a rather unpleasant taste with some exceptions like egg white where the pH increases to around 9.2, as CO_2 is lost from the egg after laying. The pH of a product can be easily determined with a pH meter. However, this value alone is not sufficient for predicting microbial spoilages. It is also desirable, for example, to know the acid responsible for a given pH, because some acids, particularly the organic acids, are more inhibitory than others.

2.2.2 Effect on Microbial Ecology and Food Spoilage

The acidity of a product plays an important role in deciding the type microflora present in food and the rate and type of its spoilage. For example, most of the meats and seafoods have a final ultimate pH of about 5.6 and above. Thus, these products are susceptible to bacterial as well as to mold and yeast spoilage. Similarly, most vegetables have higher pH values than fruits, and thus vegetables would be more prone to bacterial than fungal spoilage since such pH values favour bacterial growth. Soft-rot producing bacteria such as *Erwinia carotovora* and pseudomonads play a significant role in their spoilage. In fruits, however, a lower pH (below 4.5) prevents bacterial growth and yeasts and molds dominate spoilage.

Fish is spoiled more rapidly than meat under chilled conditions. This is due to the fact that the pH of post-rigor mammalian muscle is around 5.6 and this contributes to the longer storage life of meat. On the other hand, fish have a pH between 6.2-6.5. *Shewanella* (formerly *Alteromonas*) mainly causes spoilage under chilled conditions. It is a pH-sensitive microbe and hence, plays a significant role in fish spoilage but not in normal meat (pH<6.0). Those fishes that have a naturally low pH such as halibut (pH~5.6) as a result have better keeping qualities than other fish. Thus, a food with inherently low pH would tend to be more stable microbiologically than a neutral food.

Upon the death of a well-rested meat animal, the usual 1% glycogen is converted into lactic acid, which directly causes a depression in pH values from about 7.4 to about 5.6. Most of the bacteria cannot tolerate lower pH, hence meat has a longer storage life. Meat from fatigued animals spoils faster than that from rested animals. This is because most of the glycogen present had already been used during its lifetime and hence, final pH attained upon completion of rigor mortis is not as low as that of a well-rested animal. Thus, bacteria are able to grow and spoil it.

The excellent keeping quality of certain foods is related to their restrictive pH, for example fruits, soft drinks, fermented milks, sauerkraut and pickles which have an acidic pH. Fruits, soft drinks, vinegar, and wines have an excellent keeping quality mainly due to pH, which falls far below the point at which bacteria normally grow. Fruits generally undergo mold and yeast spoilage, and this is due to the capacity of these organisms to grow at pH values < 3.5, which is considerably below the minima for most food spoilage and all food poisoning bacteria.

Some foods have a low pH because of inherent acidity; others, for example, the fermented products like sauerkraut, pickles and fermented milks have a low pH because of acidity produced due to the activity of microorganisms. This acidity is also known as biological acidity and is generally due to the accumulation of lactic acid during fermentation. Regardless of the source of acidity, the effect upon keeping quality appears to be the same. This ability of low pH to restrict microbial growth has been employed since the earliest times for preservation of foods using acetic acid and lactic acids.

2.2.3 Inhibition of Microbes by Weak Acids

With the exception of those soft drinks that contain phosphoric acid, in most other acidic foods acidity is due to the presence of weak organic acids. These do not dissociate completely into protons and conjugate base in solution but establish equilibrium:

$$HA \rightleftarrows H^+ + A^-$$

The partial dissociation of weak acids, such as acetic acid, plays an important role in their ability to inhibit microbial growth. Although addition of strong acids has a more profound effect on pH but at the same pH, they are less inhibitory than weak lipophilic acids. This is because microbial inhibition by weak acids is directly related to the concentration of undissociated acid (Figure 2.1). These undissociated lipophilic acid molecules can pass freely through the membrane, in doing so they pass from an external environment of low pH where the equilibrium favours the undissociated molecule to the high pH of the cytoplasm. At this higher pH, the equilibrium shifts in favour of the dissociated molecule, so the acid ionizes producing protons. These protons tend to acidify the cytoplasm. The cell tends to maintain its internal pH by expelling protons leaking in. This process requires energy and the microbe diverts energy from growth related functions to removing protons from the cell thereby slowing its growth. The burden on the cell becomes too great. The cytoplasmic pH drops to a level where growth is no longer possible and the cell eventually dies. Strong acids on the other hand dissociate completely into protons and conjugate base in solution. These dissociated acid molecules cannot pass freely through the cell membrane. Hence there is not much change in the pH of the cytoplasm. As a result these are less inhibitory than weak acids at the same pH.

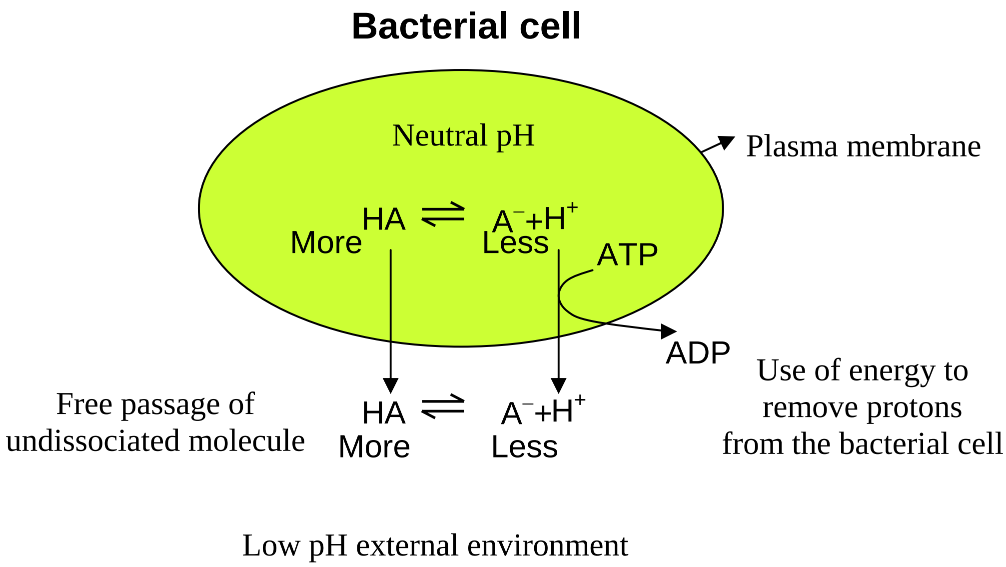

Figure 2.1: Inhibition of bacterial growth by weak acids

2.2.4 Buffers in Foods

Some foods are better able to resist changes in pH than others. These tend to resist changes in pH since these are buffered and the ability to resist changes in pH is known as buffering capacity. The buffers are the compounds present in food that resist changes in pH and thus are important. These are especially effective within a certain pH range. Buffers permit an acid (or alkaline) fermentation to go on longer with a greater yield of products and organisms than would otherwise be possible. In general, meats are more buffered than vegetables. Contributing to the buffering capacity of meats are their various proteins. Vegetables are generally low in proteins and consequently lack the buffering capacity to resist changes in their pH by the growth of microorganisms. Hence these permit an appreciable decrease in pH with the production of small amounts of acid by the lactic acid bacteria during the early part of sauerkraut and pickle fermentations. This is desirable since it enables the lactic acid bacteria to suppress the undesirable pectin-hydrolyzing and proteolytic organisms which cause spoilage. Low buffering power makes for a more rapidly appearing succession of microorganisms during fermentation than high buffering power. Milk is fairly high in protein (a good buffer) and therefore permits considerable growth and acid production by lactic acid bacteria during the manufacture of fermented milks before growth is suppressed.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Why do fishes spoil more rapidly than meat?

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2. Why does the meat from fatigued animal spoil faster than that from a well-rested animal?

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3. What is biological acidity?

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4. Why are the weak organic acids more inhibitory to growth of microorganisms than the strong acids?

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5. How does adverse pH affect the microorganism?

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2.3 MOISTURE REQUIREMENT/WATER ACTIVITY

One of man's oldest methods of preserving foods is drying or desiccation. The preservation of foods by drying is a direct result of removal of moisture. Microorganisms need water for growth. Without water no growth can occur. The exact amount of water needed for growth of microorganisms varies. This water requirement of microorganisms is best expressed in terms of available water or water activity a_w, the vapour pressure of the solution (of solutes in water in most foods) divided by the vapour pressure of the solvent (usually water). Thus a_w, for pure water would be 1.00. The water activity depends on the number of molecules and ions present in solution, rather than their size. Thus a compound like sodium chloride, which dissociates into two ions in solution, is more effective at reducing the water activity than a compound like sucrose on mole-to-mole basis.

2.3.1 Effect on Microbial Growth and Activity

Bacteria require higher values of a_w for growth than fungi. Gram-negative bacteria have higher requirements than gram positives. Most spoilage bacteria do not grow below a_w 0.91, while spoilage molds can grow as low as 0.80. However, food-poisoning bacteria like *Staphylococcus aureus* can grow at a_w as low as 0.86, while *Clostridium botulinum* does not grow below 0.94. Yeasts and molds can grow over a wider a_w range than bacteria. The lowest a_w values for bacteria is 0.75 for halophilic (meaning salt-loving) bacteria, while xerophilic (dry-loving) molds and osmophilic (preferring high osmotic pressures) yeasts can grow at a_w values of 0.65 and 0.60, respectively. The limiting value of water activity for the growth of microorganisms is about 0.6 and below this value the spoilage of foods is not due to microorganisms but may be due to insect damage or chemical reaction such as oxidation. At a water activity of 0.6, corresponding to a water potential of -68MPa (Mega Pascals), the cytoplasm would need to contain very high concentrations of an appropriate compatible solute and it is probable that the macromolecules such as DNA would no longer function properly and active growth may stop.

Most bacteria grow well in a medium with a water activity a_w approaching 1.00 (at 0.995 to 0.998), i.e., they grow best in low concentrations of sugar or salt. Culture media for most bacteria contain not more than 1 per cent of sugar and 0.85 per cent of sodium chloride (physiological salt solution). As little as 3 to 4 percent sugar and 1 to 2 percent salt may inhibit some bacteria. The optimal a_w and the lower limit of a_w for growth vary with the bacterium, as well as with food, temperature, pH, and the presence of oxygen, carbon dioxide, and inhibitors. The optimal a_w and the lower limit of a_w for growth is lower for bacteria which are able to grow in high concentrations of sugar or salt. Some examples of lower limits of a_w for growth of some food bacteria are given in Table 2.2. These figures would vary depending on conditions used for growth of the microorganisms as mentioned above.

Table 2.2: Minimum a_w values for growth of microorganisms of importance in food

Organisms	Water activity (a_w)	Organisms	Water activity (a_w)
Groups		**Specific organisms**	
Most spoilage bacteria	0.90	*Pseudomonas* spp.	0.97
Most spoilage yeasts	0.88	*Escherichia coli*	0.96
Most spoilage molds	0.80	*Bacillus subtilis*	0.95
Halophilic bacteria	0.75	*Enterobacter aerogenes*	0.945
Xerophilic molds	0.61	*Clostridium botulinum*	0.93
Osmophilic yeasts	0.60	*Staphylococcus aureus*	0.86

Molds differ considerably in optimal a_w and range of a_w for the germination of asexual spores. The minimal a_w for spore germination is as low as 0.62 for some molds and as high as 0.93 for others (e.g., *Mucor*, *Rhizopus*, and *Botrytis*). Each mold also has an optimal a_w and range of a_w for growth. Examples of optimal a_w are 0.98 for *Aspergillus* sp., 0.995 to 0.98 for *Rhizopus* sp., and 0.9935 for *Penicillium* sp. The a_w would have to be below 0.62 to stop all chances for mold growth, although a_w below 0.70 inhibits most molds that cause food spoilage. The reduction of the a_w below the optimum for a mold delays spore germination and reduces the rate of growth and therefore is an important factor in food preservation. Many of the molds can grow in foods with a_w approaching 1.00 (pure water).

With a reduction of water activity of food, the number of microorganisms capable of maintaining active growth in it decreases. On the other hand, there are microorganisms that grow better at reduced $a_{w.}$ These microorganisms are generally associated with foods having low water activity. Since low water activities are associated with three distinct types of food, the following three terms are used to describe the microorganisms especially associated with these foods:

i) **Halotolerant** – able to grow in the presence of high concentrations of salt

ii) **Osmotolerant** – able to grow in the presence of high concentrations of nonionized organic compounds such as sugars.

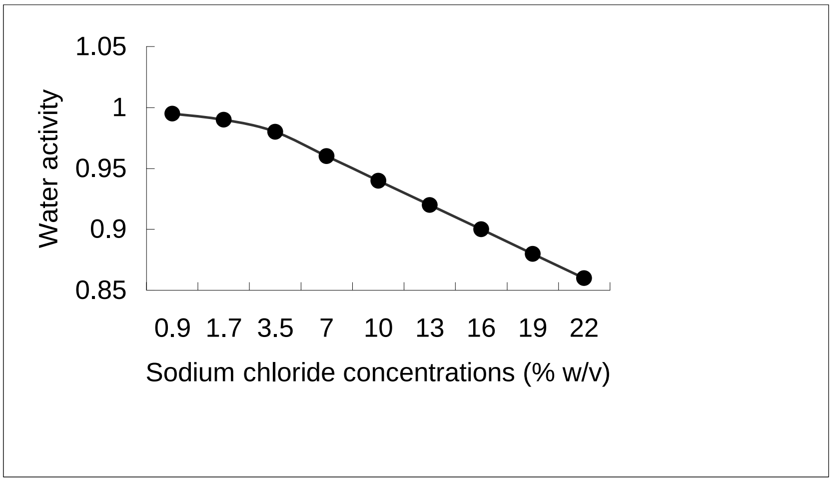
iii) **Xerotolerant** – able to grow on dry foods.

The halobacteria are obligately halophilic and cannot grow in the absence of high concentration of salt.

2.3.2 Ways of Reducing Water Activity

Water is made unavailable in various ways:

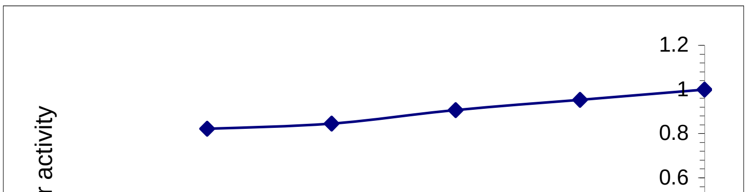
1. *Solutes and ions tie up water in solution.* Solutes lower a_w and this reduction in a_w depends on the total concentration of dissolved molecules and ions. Since these bind to water molecules, there is reduction in a_w. Therefore, an increase in the concentration of dissolved substances such as sugars and salts is in effect a drying of the material (Graph 2.1). Not only is water tied up by solutes, but also water tends to leave the microbial cells by reverse osmosis to maintain equilibrium between the concentration of solute outside and inside the cells.



Graph 2.1: Effect of sodium chloride concentration on water activity

2. *Hydrophilic colloids (gels) make water unavailable.* As little as 3 to 4 percent agar in a medium may prevent bacterial growth by leaving too little available moisture.

3. *Water of crystallization or hydration is usually unavailable to microorganisms*. Water itself, when crystallized as ice, no longer can be used by microbial cells. The a_w of water-ice mixtures (vapour pressure of ice divided by vapour pressure of water) decreases with a decrease in temperature below 0^oC (Graph 2.2). In a food, as more and more ice is formed, the concentration of solutes in the unfrozen water increases, thus lowering available water and thereby it's a_w is reduced.



Graph 2.2: Effect of temperature on water activity

The water activity a_w varies with temperature; these variations are only slight within the range of temperatures that permit microbial growth. Variations in temperature increase in importance with increasing concentrations of solutes and increasing effects on ionization of solutes.

Each microorganism has a maximal, optimal, and minimal a_w for growth. As the a_w is reduced below the optimal level, there is a lengthening of the lag period of growth, a decrease in the rate of growth and a decrease in the amount of cell substance synthesized, changes that vary with the organism and with the solute employed to reduce a_w. This range depends on a number of factors which are mentioned below.

2.3.3 Factors Affecting Water Requirement

Factors that may affect a_w requirements of microorganisms include:

1. *Kind of solute employed to reduce the a_w*: For some organisms, like molds, the lowest a_w for growth is independent of the kind of solute used. For other organisms, however, lower limiting a_w values differ from solute to solute. For example potassium chloride usually is less toxic than sodium chloride, and it in turn is less inhibitory than sodium sulphate. Thus, sodium sulphate at a lower concentration may be as effective in reducing a_w as potassium chloride at a higher concentration.

2. *Nutritive value of the culture medium*: In general, the better the medium for growth, the lower the limiting a_w permitting growth of microorganism.

3. *Temperature*: Most organisms have the greatest tolerance to low a_w at about optimal temperatures.

4. *Oxygen supply*: Growth of aerobes takes place at a lower a_w in the presence of air than in its absence, and the reverse is true of anaerobes.

5. *pH*: Most organisms are more tolerant of low a_w at pH values near neutrality than in acid or alkaline media.

6. *Inhibitors*: The presence of inhibitors narrows the range of a_w for growth of microorganism.

Each organism has its own characteristic optimal a_w and its own range of a_w for growth in a given set of environmental conditions. This range of a_w permitting growth is narrowed if any of the above mentioned environmental factors are not optimal and is narrowed still more if two or more conditions are not favourable. An unfavourable a_w will result not only in a reduction in the rate of growth but will also reduce the yield of cells. The delay (lag) in initiation of growth or germination of spores will be more under more unfavourable a_w of the substrate. It is known that growth of at least some cells may occur in high numbers at reduced a_w values, but the production of certain extracellular products may be limited or these may not be produced at all. For example, reduced a_w results in the cessation of enterotoxin B production by *Staphylococcus aureus* even though high numbers of cells are produced at the same time This often is as important in food preservation as reduction in the rate of growth of the organism. Microorganisms that can grow in high concentrations of solutes, e.g., sugar and salt, obviously have a low minimal a_w. Halophilic bacteria require a certain minimal concentration of dissolved sodium chloride for growth. Osmophilic yeasts grow best in high concentrations of sugar.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List out the types of microorganisms associated with foods having low water activity.

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2. Define water activity.

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3. How water is made unavailable to microorganisms?

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4. Describe the factors that may affect a_w requirements of microorganisms.

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2.4 OXIDATION REDUCTION POTENTIAL

The tendency of a substrate to accept or donate electrons, is termed its redox potential (*E*h). The O/R potential of a substrate may be defined generally as the ease with which the substrate loses or gains electrons. When a substrate loses electrons, the substrate is oxidized while a substrate that gains electrons becomes reduced. Therefore, a substance that readily gives up electrons is a good reducing agent, while one that readily takes up electrons is a good oxidizing agent. In the equation below, this is represented in its most general form to include the many redox reactions, which also involve protons and have the overall effect of transferring hydrogen atoms.

$$[\text{Oxidant}]+H^{+}+ne \rightleftarrows [\text{Reductant}]$$

Where *n* is the number of electrons, e, transferred.

The tendency of an atom or molecule to accept or donate electrons is expressed as its standard redox potential, *E*o'. When electrons are transferred from one compound to another, a potential difference is created between the two compounds. This difference may be measured by use of an appropriate instrument and expressed as millivolts (mv). It can be measured against an external reference by an inert metal electrode, usually platinum. The more highly oxidized a substance, the more positive will be its electrical potential, and the more highly reduced a substance, the more negative will be its electrical potential.

2.4.1 Redox Couples in Food

Pair of oxidizing and reducing agents present in food are known as redox couples. A large positive *E*o' of food indicates that the oxidized species of the couple is a strong oxidizing agent and the reduced form only weakly reducing. A large negative *E*o' of food indicates the reverse. When the concentration of oxidant and reductant is equal, a zero electrical potential exists. The relative proportions of oxidized and reduced species present will also influence the measured Eh. If the balances of the various redox couples present favours the oxidized state then there will be a tendency to accept electrons from the electrode creating a positive potential, which signifies an oxidizing-environment. If the balance is reversed, the sample will tend to donate electrons to the electrode, which will then register a negative potential – a reducing environment.

With the notable exception of oxygen, most of the couples present in foods, *e.g.* glutathione and cysteine in meats and ascorbic acid and reducing sugars in plant products, would on their own tend to establish reducing conditions. Oxygen, which is present in the air at a level of around 21 %, is usually the most influential redox couple in food systems. It has a high *E*o' and is a powerful oxidizing agent. If sufficient air is present in food, a high positive potential will result and most other redox couples present will, if allowed to equilibrate, be largely in the oxidized state. Hence, increasing the access of air to food material by chopping, grinding or mincing will increase its *E*h. Similarly, exclusion of air as in modified vacuum packing or canning will reduce the *E*h.

2.4.2 Effect of Microbial Growth on Redox Potential of Food

Microbial growth in food reduces its *E*h. This is usually because during their growth, microorganisms consume oxygen and produce reducing compounds such as hydrogen. Oxygen is the most important terminal electron accepter in the electron transport chain, especially in case of aerobes. During passage of electrons through the electron transport chain, microorganisms generate energy and thereby oxygen is depleted. As the oxygen content of the medium decreases, so the redox potential declines from a positive potential to a negative potential.

The decrease in *E*h as a result of microbial activity is the basis of some rapid tests for determination of microbial load of food, particularly dairy products. Redox dyes such as methylene blue or resazurin are used to indicate changes in *E*h, which are correlated with microbial levels. These dyes become colourless when these are reduced. The time taken for reduction of the dyes will be inversely proportional to the microbial load of food i.e. more the microorganisms in food, less is the time taken for dye to be reduced and *vice versa*. The factors influencing redox potential of foods are summarized in Table 2.3 given below:

Table: 2.3 Factors affecting redox potential of foods

1. Redox couples present
2. Ratio of oxidizing species to reducing species
3. pH
4. Poising capacity
4. Availability of oxygen
5. Microbial activity

2.4.3 Effect on Microbial Growth and Ecology

Redox potential exerts an important selective effect on the microflora of a food since it will decide the type of microorganism which can grow in that food. Microbial growth can occur over a wide spectrum of redox potential. However, individual microorganisms have their own redox ranges over which they can grow. They are classified into one of several physiological groups on the basis of the redox range over which they can grow and their response to oxygen. Based on their ability to use free oxygen, microorganisms have been classified as

1. **Aerobic** when they require free oxygen.
2. **Anaerobic** when they grow best in the absence of free oxygen.
3. **Facultative** when they grow well either aerobically or anaerobically.

Molds are aerobic, most yeast grow best aerobically and bacteria may be aerobic, anaerobic, or facultative. A high (oxidizing) potential favours aerobes but will permit the growth of facultative organisms also, and a low (reducing) potential favours anaerobic or facultative organisms. Growth of an organism may alter the O-R potential of a food enough to inhibit other organisms. Anaerobes, for example, may lower the O-R potential to a level which is inhibitory to aerobes.

Obligate aerobes are those organisms that generate their energy from oxidative phosphorylation using oxygen as the terminal electron acceptor. Consequently, they have a requirement for oxygen and a high *E*h and will predominate at food surfaces exposed to air or where air is readily available, for example, pseudomonads, such as *Pseudomonas fluorescens*, which grows at an *E*h of +100 to +500 mv, and other oxidative Gram-negative rods. These grow on meat surfaces and produce slime and off-odours. *Bacillus subtilis (E*h -100 to +135 mv) produces ropiness in the open texture of bread and *Acetobacter* species growing on the surface of alcoholic beverages oxidize ethanol to acetic acid to produce vinegar or spoil the alcoholic beverage.

Plant juices, tend to have *E*h values of +300 to +400 mv. It is not surprising to find that aerobic bacteria and molds are the common cause of spoilage of products of this type. Minced meats have *E*h values of around +200 mv while in solid meats the *E*h is generally around -200 mv. Cheeses have *E*h values on the negative side from –20 to around –200 mv.

Obligate anaerobes grow only at low or negative redox potentials and require absence of oxygen. Anaerobic metabolism gives the organism a lower yield of utilizable energy than aerobic respiration. A reducing environment minimizes the loss of reducing power from the microbial cell and thus, is favoured. Hence, presence of oxygen, which provides an oxidizing environment to the microbes is not favoured. However, for many anaerobes, oxygen itself exerts a specific toxic effect. For example, *Clostridium acetobutylicum* can grow at an *E*h as high as +370 mv maintained by ferricyanide, but would not grow at +110mv in an aerated culture. This effect is due to the inability of obligate anaerobes to scavenge and destroy toxic products of molecular oxygen such as hydrogen peroxide and superoxide anion radical (0_2^-) produced by one electron reduction of molecular oxygen. They lack the enzymes catalase and superoxide dismutase, which catalyse the breakdown of these radicals.

Thus, in a highly oxidized food, there will be a predominance of aerobic organisms especially at food surfaces exposed to air. Whereas, in food with negative *E*h, the anaerobic microflora requiring reduced conditions will be favoured. For example, anaerobic bacteria do not multiply until the onset of rigor mortis (stiffening of body after death) of muscles of horse because of the high *E*h (+250 mv) in prerigor meat. At 30 h postmortem (after death), the *E*h falls to about -130 mv in the absence of bacterial growth and this low *E*h values favour the growth of obligate anaerobes like *Clostridium.* Obligate anaerobes, such as clostridia, have the potential to grow wherever conditions are anaerobic such as deep in meat tissues and stews, in vacuum packs and canned foods causing spoilage and C. *botulinum* is of major public health concern, since it causes botulism.

Aerotolerant anaerobes are incapable of aerobic respiration, but can nevertheless grow in the presence of air. Many lactic acid bacteria fall into this category. They can only generate energy by fermentation and lack both catalase and superoxide dismutase, but are able to grow in the presence of oxygen because they have a mechanism for destroying superoxide.

Microorganisms affect the *E*h of their environment during growth. This is true especially of aerobes, which can lower the *E*h of their environment while anaerobes cannot. As aerobes grow, oxygen in the medium is depleted, resulting in the lowering of *E*h. Growth is not slowed, however, due to the ability of cells to make use of oxygen donating or hydrogen-accepting substances in the medium. The result of this is that the medium becomes poorer in oxidizing and richer in reducing substances. Microorganisms can reduce the *E*h of a medium by their production of certain metabolic by-products such as hydrogen sulphide, which has the capacity to lower *E*h to –300 mv. Since hydrogen sulphide reacts readily with oxygen, it will accumulate only in anaerobic environments.

2.4.4 Poising Capacity of Food

As redox conditions change, there will be some resistance to change in a food's redox potential. This is known as poising capacity of food. This capacity is dependent on the concentration of the redox couple. Poising is greatest when the two components of a redox couple are present in equal amounts.

Most fresh plant or animal foods have a low and well-poised O-R potential in their interior: the plants because of reducing substances such as ascorbic acid and reducing sugars and the animal tissues because of SH (sulfhydryl) and other reducing groups. As long as the plant or animal cells respire and remain active, they tend to poise the O-R system at a low level, resisting the effect of oxygen diffusing from the outside. Therefore, a piece of fresh meat or a fresh whole fruit would have aerobic conditions only at and near the surface. The meat could support aerobic growth of slime-forming or souring bacteria at the surface at the same time as anaerobic putrefaction could be proceeding in the interior.

Processing procedures may alter this situation. For example, heating may reduce the poising power of the food by destroying or altering the reducing and oxidizing substances present and also allow more rapid diffusion of oxygen inward, either because of the destruction of poising substances or because of changes in the physical structure of the food. Processing also may remove oxidizing or reducing substances. For example, clear fruit juices loose reducing substances by their removal during extraction and filtration and therefore become more favourable to the growth of yeasts than the original juice containing the pulp.

In the presence of limited amounts of oxygen the same aerobic or facultative organisms may produce incompletely oxidized products, such as organic acids, from carbohydrates, while with plenty of oxygen available, complete oxidation to carbon dioxide and water might result. Protein decomposition under anaerobic conditions may result in putrefaction, whereas under aerobic conditions, the products are likely to less obnoxious. Thus, the redox potential of the food would decide the course of spoilage and the type of end products being produced due to microbial activities.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define redox potential.

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2. Enlist the physiological groups of microorganisms based on their oxygen requirement.

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3. Define the poising capacity of food.

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4. How is the poising capacity of food destroyed?

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5. Enlist the factors which affect the redox potential of food.

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2.5 NUTRIENT CONTENT

Microorganisms use foods as a source of nutrients and energy. Each kind of microorganism has a definite range of food requirements. For some species that range is wide and growth takes place in a variety of substrates e.g. coliform bacteria; but others, e.g., many of the pathogens, being fastidious in their nutrient requirements can grow in limited kinds of substrates. The better the medium for an organism, the wider the ranges of temperature, pH, and a_w over which growth can take place.

The food based on their nutrient composition can be classified as (1) foods for energy, (2) foods for growth, and (3) accessory food substances, or vitamins, which may be necessary for energy or growth.

2.5.1 Foods for Energy

The carbohydrates, especially the sugars, are most commonly used as an energy source, but other carbon compounds may also serve the purpose, e.g., esters, alcohols, peptides, amino acids, organic acids and their salts. Comparatively few organisms can utilize complex carbohydrates, e.g., cellulose and starch. Microorganisms differ even in their ability to use some of the simpler soluble sugars. Many organisms cannot use the disaccharide lactose (milk sugar) and therefore do not grow well in milk. Some yeast do not attack maltose. Most organisms, if they utilize sugars at all, can use glucose. The ability of microorganisms to hydrolyze pectin, which is characteristic of some kinds of bacteria and many molds, is important in the softening or rotting of fruits and vegetables or fermented products got from them. The ability to synthesize amylolytic (starch degrading) enzymes will favour the growth of an organism on cereals and other starchy products. The addition of fruits containing sucrose and other sugars to yoghurt increases the range of carbohydrates available and allows the development of a more diverse spoilage microflora of yeasts.

Bacteria differ in their ability to utilize different foods as a source of energy. Some can use a variety of carbohydrates, e.g., the coliform bacteria and *Clostridium* spp., and others only one or two. Some can use other carbon compounds like organic acids and their salts, alcohols, and esters *(Pseudomonas* spp.). Some can hydrolyze complex carbohydrates, although others cannot.

A limited number of microorganisms can obtain their energy from fats but do so only if a more readily usable energy food, such as sugar, is absent. First, the fat must be hydrolyzed with the aid of lipase to glycerol and fatty acids, which then can serve as energy source for the hydrolyzing organism or others microbes that grow on products of lipid hydrolysis. Aerobic microorganisms are more commonly involved in the decomposition of fats than anaerobic ones, and the lipolytic organisms usually are also proteolytic.

Split products of proteins, for example, peptides and amino acids, serve as an energy source for many proteolytic organisms when a better energy source is lacking. These also serve as source of energy for some non-proteolytic organisms. Meats for example, may be low in carbohydrate and therefore will be decomposed by proteolytic species, e.g., *Pseudomonas* spp.

Molds in general can utilize many kinds of foods as energy source, ranging from simple to complex. Most of the common molds possess a variety of hydrolytic enzymes and some are grown for their amylases, pectinases, proteinases, and lipases.

Not only is the kind of energy food important but also its concentration in solution and hence it's osmotic effect and the amount of available moisture, which will determine its growth rate. For a given percentage of sugar in solution, the osmotic pressure will vary with the weight of the sugar molecule, Therefore, a 10% solution of glucose has about twice the osmotic pressure of a 10% solution of sucrose or maltose; i.e., it ties up twice as much moisture. Molds can grow in the highest concentrations of sugars and yeasts in fairly high concentrations but most bacteria grow best in fairly low concentrations. There are, of course, some exceptions to this generalization: osmophilic yeasts grow in as high concentrations of sugar as molds and some bacteria can grow in fairly high concentrations of sugar.

An adequate supply of foods for growth will favour utilization of the foods for energy. More carbohydrate will be used if a good nitrogen food is present in sufficient quantity than if the nitrogen is in poor supply. Organisms requiring special accessory growth substances might be prevented from growing if one or more of these vitamins were lacking, and thus the whole course of decomposition might be altered due to a change in the microflora.

2.5.2 Foods for Growth

Microorganisms differ in their ability to use various nitrogenous compounds as a source of nitrogen for growth. The primary nitrogen sources utilized by heterotrophic microorganisms are amino acids. A large number of other nitrogenous compounds may serve this function for example, nucleotides, free amino acids, peptides and proteins. Simple compounds such as amino acids will be utilized by most of the organisms before they utilize complex compounds such as high molecular weight proteins. The nitrogen requirements of some bacteria such as *Pseudomonas* spp. may be satisfied by simple compounds like ammonia or nitrates whereas for others like lactics, more complex compounds like amino acids, peptides, or proteins may be utilized or even required.

Many molds are proteolytic, but comparatively few bacteria and very few yeast are actively proteolytic. Proteolytic bacteria grow best at pH values near neutrality and are inhibited by acidity. Only exceptions are the acid-proteolytic bacteria that hydrolyze protein while producing acid. Carbon for growth for most of the microorganisms is derived from organic compounds but some can use carbon dioxide also.

The minerals required by microorganisms are nearly always present at the low levels required.

2.5.3 Accessory Food Substances or Vitamins

Bacteria also vary in their need for vitamins or accessory growth factors. Some microorganisms are unable to synthesize some or all of the vitamins needed for their growth. For example, *Staphylococcus aureus* synthesizes part while *Pseudomonas* or *Escherichia coli* all of the factors needed. The lactics and many pathogens must have all of the vitamins furnished. Most natural plant and animal foodstuffs contain an array of these vitamins, but some may be low in amount or lacking. For example, meats are high in B vitamins and fruits are low, but fruits are high in ascorbic acid.

Microorganisms may require B vitamins in low quantities and most of the natural foods have an abundant quantity of these. Gram positive bacteria are the least synthetic and must, therefore, be supplied with one or more of these compounds before they will grow. Gram negative bacteria and molds are able to synthesize most of their requirements. Consequently, these two groups of organisms may be found growing on foods low in B vitamins. Fruits tend to be lower in B vitamins than meats. Thus, the usual spoilage of fruits is by molds rather than bacteria since fruits also have a low pH and positive *E*h, which favour mold growth.

Egg white contains biotin but also contains avidin, which ties it up, making it unavailable to microorganisms and thus eliminate spoilage of eggs through biotin requiring organisms. The processing of foods often reduces the vitamin content. For example, thiamine, pantothenic acid, folic acid and ascorbic acid (in air) are heat-labile. Drying causes a loss in vitamins such as thiamine and ascorbic acid. Even storage of foods for long periods, especially if the storage temperature is elevated, may result in a decrease in the level of some of these growth factors.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the effect of sugar concentration on microbial growth?

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2.6 BIOLOGICAL STRUCTURE

The plants and animals that serve as food sources have all evolved mechanisms of defense against the invasion and proliferation of microorganisms. By taking these natural phenomena into account, one can make effective use of these in preventing the microbial spoilage of the products.

2.6.1 Antimicrobial Barriers

The inner parts of whole, healthy tissues of living plants and animals are either sterile or low in microbial content. Therefore, unless opportunity has been given for their penetration, spoilage organisms within raw food may be few or lacking.

The first barrier is the integument: a physical barrier to protect the food, e.g., the shell on eggs, the skin on poultry, the shell on nuts and the rind or skin on fruits and vegetables, or these may be surrounded by natural wax. It is usually composed of macromolecules relatively resistant to degradation and provides an inhospitable environment for microorganisms either with a low water activity or nutrients deficiency or antimicrobial compounds e.g. short chain fatty acids on animal skin, essential oils on plant surfaces etc. This physical protection to the food may not only help in its preservation but may also determine the kind, rate and course of spoilage. Layers of fat over meat may protect that part of the flesh, or scales may protect the outer part of the fish.

2.6.2 Effect of Destruction of Microbial Barriers

Physical damage to the integument allows microbial invasion of the underlying nutrient-rich tissues and it is a common observation that damaged fruits and vegetables deteriorate more rapidly than entire products and that this process is initiated at the site of injury. Consequently, it is important that during harvesting and transport these barriers are maintained intact as far as possible.

An increase in exposed surface, brought about by peeling, skinning and chopping may serve not only to distribute spoilage organisms but also to release juices containing food materials for the microorganisms. The disintegration of tissues by freezing may accomplish a similar result. In meat the growth of spoilage bacteria takes place mostly in the fluid between the small meat fibers and it is only after rigor mortis that much of this food material is released from the fibers to become available to spoilage organisms.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the role of antimicrobial barriers in preventing food spoilage by microorganisms?

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2. What happens when integument is physically damaged?

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2.7 INHIBITORY SUBSTANCES

These may be originally present in the food, added purposely or accidentally, or developed there by growth of microorganisms or by processing methods. These may prevent growth of all microorganisms or, more often, may deter certain microorganisms. The mechanism of action for nearly all antimicrobials can be classified into one or more of the following groups: (1) reaction with the cell membrane, (2) inactivation of essential enzymes, or (3) destruction or functional inactivation of genetic material.

2.7.1 Biological Inhibitory Substances Originally Present in Food

The stability of some foods against attack by microorganisms is due to the presence of certain naturally occurring substances e.g. plants such as mustard, horseradish, watercress, cabbage and other brassicas produce antimicrobial isothiocyanates (mustard oils) (Fig. 2.2) and in *Allium* species (garlic, onions and leeks) thiosulfinates such as allicin. Antimicrobials collectively known as phytoalexins are produced by many plants in response to microbial invasion, for example phaseollin an antifungal compound is produced in green beans.
Many natural constituents of plant tissues such as pigments, alkaloids and resins also have antimicrobial properties. Benzoic and sorbic acids found in cranberries and mountain ash berries respectively are commonly used in their pure forms as food preservatives. The anthocyanins are a group of water-soluble pigments, which occur naturally in fruits. The aglycone portion of these compounds, the anthocyanidins, has antimicrobial powers against several bacterial spp.

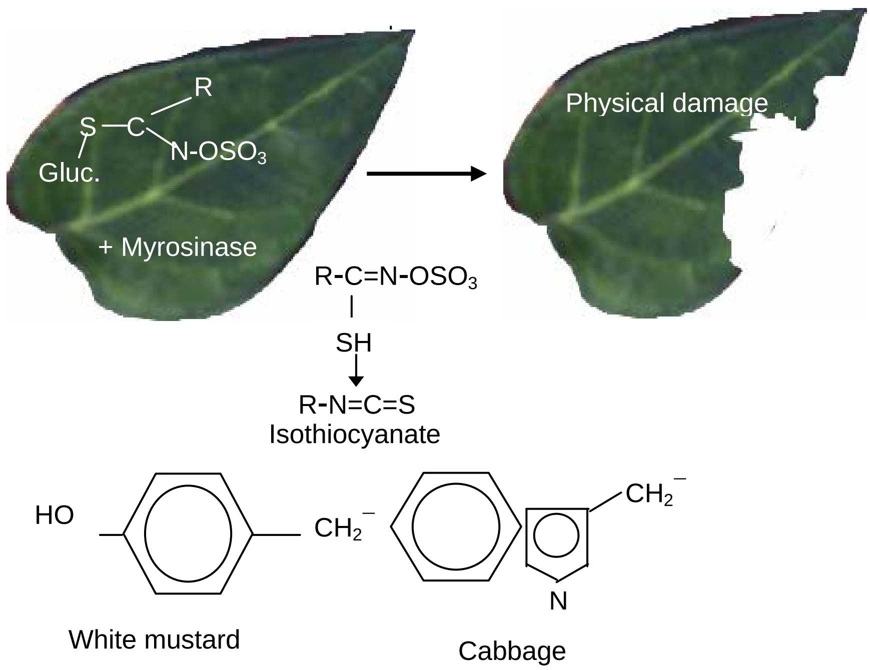

Figure 2.2: Production of plant antimicrobials as a result of physical damage

Some spices are known to contain essential oils that possess antimicrobial activity e.g. eugenol in cloves, allicin in garlic, cinnamic aldehyde and eugenol in cinnamon, allspice (pimento) and cloves, allyl isothiocyanate in mustard, eugenol and thymol in sage and carvacrol (isothymol) and thymol in oregano etc. As a consequence, herbs and spices may contribute to the microbiological stability of foods in which they are used. It has, for example, been claimed that inclusion of cinnamon in raisin bread retards mould spoilage. However, in some cases, they can be a source of microbial contamination leading to spoilage or public health problems. Outbreaks of botulism associated with crushed garlic in oil and home canned peppers demonstrate that even in relatively high concentrations plant antimicrobials are not a complete guarantee of safety.

These antimicrobial components differ in their spectrum of activity and potency. They are present at varying concentrations in the natural product and are frequently at levels too low to have any effect. Humulones contained in the hop resin impart the characteristic bitterness of the product but have also been shown to possess activity against the common beer spoilage organisms, lactic acid bacteria.

Antimicrobial oleuropein from green olives and its aglycone are also inhibitory to lactic acid bacteria and if not removed at this early stage, they would prevent the necessary fermentation occurring subsequently. The hydroxycinnamic acid derivatives (coumaric, ferulic, caffeic and chlorogenic acids) found in fruits, vegetables, tea, molasses and other plant sources all show antibacterial and some antifungal activity.

Animal products too, have a range of non-specific antimicrobial constituents, for example egg white or albumen possesses a variety of inhibitory components (Table 2.4). Similar factors can also be found in milk, however, in lower concentrations e.g. enzyme lysozyme which catalyses the hydrolysis of glycosidic linkages in peptidoglycan. Destruction or weakening of this layer causes the cell to rupture (lyse) under osmotic pressure. Lysozyme is most active against gram- positive bacteria, where the peptidoglycan is more readily accessible, but it can also kill gram- negatives if their protective outer membrane is damaged in some way.

Table 2.4: Antimicrobial substances in egg and milk

Egg	Milk
Ovotransferrin (conalbumin)	Lactoferrin
Lysozyme	Lysozyme
Avidin	-
Ovoflavoprotein	-
Ovomucoid and ovoinhibitor	-
-	Lactoperoxidase
-	Immunoglobulin

Other components limit microbial growth by restricting the availability of key nutrients. Ovotransferrin and conalbumin in egg white and lactoferrin in milk are proteins that scavenge iron from the medium. Iron is an essential nutrient for all bacteria. Infact, lysozyme with conalbumin provides fresh eggs with a fairly efficient antimicrobial system. In addition, egg white has powerful cofactor-binding proteins such as avidin and ovoflavoprotein, which remove biotin and riboflavin restricting the growth of those bacteria for which they are essential nutrients.

Cows' milk contains several other antimicrobial substances including conglutinin, lactenins, anticoliform factor and the lactoperoxidase system.

Casein as well as some free fatty acids that occur in milk have also been shown to be antimicrobial.

2.7.2 Inhibitory Substances Developed/ Destroyed in Food due to the Activity of Microorganisms

Microorganism growing in food may produce one or more substances inhibitory to other organisms, products such as acids, alcohols, peroxides, or even antibiotics. Propionic acid produced by the propionibacteria in Swiss cheese is inhibitory to molds; alcohol formed in quantity by wine yeasts inhibits competitors; and nisin a polypeptide produced by *Streptococcus lactis* may be useful in inhibiting lactate fermenting, gas-forming clostridia during curing of cheese. These may however, be undesirable during the manufacturing process since these would slow down some of the essential lactic acid streptococci. *Streptococcus cremoris* produces an inhibitor named diplococcin. The most pathogenic member of genus - *S. pyogenes* forms an inhibitor, streptococcin A-FF22. Streptococcin A-PF22 had many properties in common with nisin.

Gram-negative organisms and molds are insensitive to nisin. However, its effectiveness against sensitive gram-positive organisms depends on the bacterial load. As the number of organisms increases, the inhibitory effectiveness of nisin decreases. Nisin can be used along with heat processing since heat treated spores become more nisin sensitive. Thus, sterility might be attained with less heat treatment than presently used thereby decreasing the fuel consumption.

In addition to inhibitory polypeptides and bacteriocins, lactic streptococci produce acids and peroxides. These add up to a formidable array of substances designed to hinder and suppress other microbes. Hence, lactic acid bacteria are excellent competitors in foods. *S. diacetylactis* produces inhibitor inhibiting a broad-spectrum of gram-positive and gram-negative organisms. The undissociated molecule is the toxic component.

There is also the possibility of the destruction of inhibitory compounds in foods by microorganisms. Certain molds and bacteria are able to destroy some of the phenolic compounds that are added to meat or fish by smoking or benzoic acid added to foods; yeasts resistant to it destroy sulfur dioxide; and lactobacilli can inactivate nisin.

2.7.3 Inhibitory Substances Developed During Processing of Food

Heating foods may result in the formation of inhibitory substances e.g. heating lipids may hasten autoxidation and make them inhibitory and browning concentrated sugar syrups may result in production of furfural and hydroxymethylfurfural, which are inhibitory to fermenting organisms. Milk also has the capacity to generate antimicrobials in the presence of hydrogen peroxide. The milk enzyme lactoperoxidase will catalyse the oxidation of thiocyanate by hydrogen peroxide to produce *inter alia* hypothiocyanate. This can kill gram-negative bacteria and inhibit gram-positives, possibly by damaging the bacterial cytoplasmic membrane.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Enlist the various mechanisms of action of inhibitory substances.

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2. Elaborate on the inhibitory substances naturally present in plants with suitable examples.

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3. Enlist all the antimicrobial constituents present in egg and milk.

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4. What is the mode of action of lysozyme?

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5. Give examples of inhibitory substances developed in food due to the activity of microorganisms.

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2.8 LET US SUM UP

Food is the substrate for growth of microorganisms. Since our foods are of plant and animal origin, all the characters of plant and animal tissues that affect the growth of microorganisms are important. In other words, food will dictate what grows or does not grow on it. Thus, knowledge about the factors that favour or inhibit growth of microorganisms is a must to make predictions about the microflora that may develop. The main factors, which influence microbial activity are pH, water activity, redox potential, nutrient composition, biological structure and presence of inhibitory substances in foods.

Each microorganism has a minimal, maximal and optimal range for pH, water activity and redox potential at which they can grow. These in turn would determine the microflora of food. Buffers in food and poising capacity of food also play an important role in deciding the succession of microorganisms and the extent of spoilage occurring in food.

Different microorganisms have different nutritional requirements. Some have a wide range while others are very fastidious in their nutritional requirements. The inability of an organism to utilize a component of food limits its growth and others with not so stringent requirements gain a competitive edge over it and predominate, thereby typifying the natural microflora of that food.

Plants and animals have also evolved mechanism of defense against invasion and proliferation of microorganisms. Antimicrobial barriers allow food to remain relatively free from microorganisms and the other inhibitory substances present in food/ produced during invasion by microorganisms tend to maintain low microbial counts in food.

These six parameters represent nature’s way of preserving plant and animal tissue from microorganisms. All these parameters have an important role to play in determining microbial ecology of food. These in turn decide the type of microbial activities likely to occur and the type of spoilage occurring. All these factors are interlinked and the changes in one factor may affect microbial requirements. By taking these natural phenomena into account, one can make effective use of each or all in preventing or retarding microbial spoilage of the products that are derived from them.

2.9 KEY WORDS

Aerobic : microorganisms are those, which require free oxygen for growth.

Anaerobic : microorganisms are those, which grow best in the absence of free oxygen.

Antibiotics : are substances produced by microorganisms which inhibit the growth of other microorganisms.

Antimicrobials : are substances which inhibit the growth of microorganisms.

Bacteriocins : are substances produced by a strain of bacterial spp. which inhibit growth of other strains of that bacterial spp.

Buffers : are the compounds that resist changes in pH.

Facultative : microorganisms are those, which grow well either aerobically or anaerobically.

Halotolerant : are those microorganisms, which are able to grow in the presence of high concentrations of salt.

Osmotolerant : are those microorganisms, which are able to grow in the presence of high concentrations of unionized organic compounds such as sugars.

Oxidising agent : is a substance that readily takes up electrons.

Phytoalexins : are a class of antimicrobials which are produced by many plants in response to microbial invasion.

Poising capacity : is the ability of food to resist change in a food's redox potential.

Proteolytic microorganisms : are those, which are able to hydrolyze proteins.

Redox potential : of a substrate may be defined generally as the ease with which the substrate loses or gains electrons.

Reducing agent : is a substance that readily gives up electrons.

Standard redox potential, *Eo*' : is the tendency of an atom or molecule to accept or donate electrons.

Water requirement or water activity a_w : is the vapour pressure of the solution (of solutes in water in most foods) divided by the vapour pressure of the solvent (usually water).

Xerotolerant : are those microorganisms which are able to grow on dry foods.

2.10 ANSWERS TO CHECK YOUR PROGRESS EXCERCISES

Check Your Progress Exercise 1

1. Fish is spoilt more rapidly than meat under chilled conditions. The pH of post-rigor mammalian muscle, around 5.6, is lower than that of fish (6.2-6.5) and this contributes to the longer storage life of meat. Those fishes that have a naturally low pH such as halibut (pH~5.6) have better keeping qualities than other fishes.

2. Your answer should include the following points:

   - pH attained upon rigor mortis of well rested animals
   - not much change in pH change in case of fatigued animal

3. Biological acidity is the acidity developed in food due to the activity of microorganisms growing in it. This generally occurs due to accumulation of lactic acid during fermentation.

4. Your answer should include the following points:

   - partial dissociation of weak acids
   - free passage of undissociated lipophilic acids into the cytoplasm
   - dissociation of lipophilic acids in the microbial cell
   - maintenance of internal pH by expulsion of protons

5. When microorganisms are grown on either side of their optimum pH range, an increased lag phase results. Adverse pH affects at least two aspects of a respiring microbial cell: the functioning of its enzymes and the transport of nutrients into the cell.

Check Your Progress Exercise 2

1. Your answer should include the Halotolerant, Xerotolerant and Osmotolerant microorganisms.

2. Water activity a_w, is the vapour pressure of the solution (of solutes in water in most foods) divided by the vapour pressure of the solvent (usually water).

3. Your answer should include the following points:

   - Solutes and ions tie up water in solution
   - Hydrophilic colloids (gels) make water unavailable
   - Water of crystallization or hydration is usually unavailable to microorganisms

4. Your answer should include the following points:

   - Kind of solute employed to reduce the a_w
   - Nutritive value of the culture medium
   - Temperature
   - Oxygen supply
   - pH
   - Inhibitors

Check Your Progress Exercise 3

1. The tendency of a substrate to accept or donate electrons, to oxidize or reduce, is termed its redox potential (*E*h).

2. Your answer should include aerobic, anaerobic and facultative microorganisms.

3. Poising capacity is the resistance to change in a food's redox potential with change in the redox conditions.

4. Your answer should include the following points:

   - Heating destroys/ alters reducing and oxidizing substances
   - Processing removes reducing and oxidizing substances

5. Factors affecting redox potential of foods are:

   - Redox couples present
   - Ratio of oxidant to reductant
   - pH
   - Poising capacity
   - Availability of oxygen
   - Microbial activity

Check Your Progress Exercise 4

1. Your answer should include the following points:

   - Concentration of sugars in food and their osmotic effect
   - Molds grow at high concentration of sugars
   - Osmophilic bacteria and yeasts grow at high concentration of sugars

Check Your Progress Exercise 5

1. Your answer should include the following points:

   - Type of physical barriers about food
   - These barriers provide inhospitable environment for the microbe
   - They determine type and rate of spoilage

2. Your answer should include the following points:

   - Physical damage allows microbial invasion into tissues
   - It distributes spoilage microbes
   - It releases juices from plant and animal tissues for microbial growth

Check Your Progress Exercise 6

1. The mechanism of action for nearly all antimicrobials can be classified into one or more of the following groups:

   a) Reaction with the cell membrane,

   b) Inactivation of essential enzymes, or

c) Destruction or functional inactivation of genetic material.

2. Your answer should include the following points:
   - Isothiocyanates – mustard oil
   - Thiosulfinates – in garlic, onions and leeks e.g. allium

3. Your answer should include the following points:
   - Antimicrobial substances present in egg
   - Antimicrobial substances present in milk

4. Your answer should include the following points:
   - Lysozyme catalyses the hydrolysis of glycosidic linkages in peptidoglycan
   - Destruction leads to cell lysis
   - Very active against gram positive bacteria

5. Your answer should include the following points:
   - Various types of inhibitory substances produced by microbes
   - Inhibitory substances produced by propionibacteria
   - Inhibitory substances produced by lactic streptococci

2.11 SOME USEFUL BOOKS

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4. Stanier, R.Y., Adelberg, E.A. and Ingraham, J. (1976) The Microbial World. Prentice-HaIl, Inc., Englewood Cliffs, N.J.

UNIT 3 INDUSTRIALLY IMPORTANT YEAST, MOLD AND BACTERIA

Structure

3.0 OBJECTIVES

After reading this unit you should be able to:

- state the fermenter, types of microorganisms involved in fermentation and their processes;
- explains the different products made by fermentation; and
- describe the waste from food processing industry and their utilization.

3.1 INTRODUCTION

Microorganism on one hand are responsible for causing a number of diseases, on the other hand they are employed to produce a number of useful products. These useful microorganisms include an array of yeasts, molds and bacteria. Traditionally, the man prepared wine, curd, vinegar and pickles using fermentation. Earlier, the term 'Fermentation' was used for the production of wine but at present it encompasses the foods made by the application of microorganisms including lactic acid bacteria (LAB). Lactic acid fermentation is one of the oldest method of preserving fruits and vegetables. Apart from contributing certain desirable physical and flavour characteristics, it also prolongs the availability and processing period of the products at relatively low cost. Many of the fermented products are made at industrial scale making use of microorganisms. Some of the fermented products and industrially important microorganisms are listed in Table 3.1.

Table 3.1: Production/synthesis of various compounds by micro-organisms

Product	Micro-organism(s) involved
Alcoholic beverages & related products	
Beer	*Saccharomyces cerevisiae*; *S. carlsbergensis*
Bourbon whiskey	*S. cerevisiae*
Cider	*S. cidri*
Palm wine	*Acetobacter* spp.; yeasts
Sake	*Aspergillus oryzae*; *Lactobacillus* spp.; *Leuconostoc* spp.; *S. cerevisiae*
Scotch whiskey	*S. cerevisiae*
Thumba	*Endomycopsis fibuliges*
Tibi	*Betabacterium vermiforme; S. intermidium.*
Vinegar	*Acetobacter* spp.
Wines	*S. cerevisiae* var. *ellispoideus*
Breads	
Idli	*Leuconostoc mesenteroids*
Rolls, cakes etc.	*S. cerevisiae*
Colour	
β-carotene	*Blakeslea trispora; Rhodotorula spp.*
Astaxanthine	*Phiffia rhodozyma*
Dairy products	
Acidophillus milk	*Lactobacillus acidophilus*
Bulgarian milk	*L. bulgaricus*
Cheeses (brie,	*Streptococcus lactis; S. cremoris*: *camembert, cheddar, S. durans; Penicillium camembertii*: *edam, P. candidum; P. roquefortii; Lactobacillus caseiroqueforte)*
Kefir	*Streptococcus lactis; L. bulgaricus; torula* spp.
Kumiss	*L. bulgaricus; L. leicuhmannii; Torula* spp.
Yoghurt	*L. bulgaricus*
Enzymes	
Amylases	*Bacillus* spp.; *Aspergillus niger; A. oryzae.*
Cellulases	*Trichoderma reesei.*
Glucose oxidases & catalase	*Corynebacterium* spp.
Invertase	*S. cerevisiae*
Lipase	*Saccharomycopsis lipolytica.*
Pectinases	*Aspergillus* spp.
Proteases	*B. licheniformis*; *B. subtilis; Aspergillus* spp.; *S. cerevisiae*

Meat and fishery products	
Country cured hams	*Aspergillus; Penicillium* spp.
Dry sausages	*Pediococcus cerevisiae*
Microbial cells as fermented products	
Bakers' yeast	*Saccharomyces cerevisiae*
Single cell	*Candida utilis; C. arborea;* protein (SCP) *Methylophilus methylotrophus; Saccharomycopsis lipolytica; Spirulina*
Mushrooms	*Agaricus bisporus*; *Morchella hortensis*
Non-beverage plant products	
Miso	*Aspergillus oryzae*
Saurkraut	*Neurospora sitophila*
Sufu	*L. delbrueckii*
Tempeh	*A. oryzae; Rhizopus oligosporus; R. oryzae*
Organic acids	
Acetic acid	*Acetobacter aceti; C. aceticum*
Citric acid	*Aspergillus niger; Saccharomycopsis lipolytica*
Lactic Acid	*Lactobacillus delbrueckii*
Polysaccharides	
Alginate	*Azotobacter vinelandii; Pseudomonas aeruginosa*
Dextrans	*Leuconostoc mesenteroids; Klebsiella; Acetobacter*
Pullulan	*Aureobasidium; Pullularia* spp.
Vitamins and Amino acids	
Riboflavin	*Eremothecium ashbyi*
Vit. B-12	*Bacillus megaterium; Streptomyces olivaceus, Propionibacterium*
Pro-Vit. A.	*Rhodotorula gravillis.*

3.2 CULTURING OF IMPORTANT MICROORGANISM

The human food supply consists basically of plants and animals or products derived from them, so our food supply can contain microorganisms in interaction with the food. The interactions between microorganisms and our food is beneficial as exemplified by many cultured products developed by fermentation and are consumed and enjoyed by many people (Bread, bear, wine etc). To produce such products microorganisms are added as pure culture or mixed cultures. However, in some cases no cultures may be added if the desired microorganisms are known to be present in sufficient numbers in the original raw material.

Starter culture, pure as well as mixed are usually employed in the manufacture of certain fermented food and dairy products. Cultures for food fermentations are selected primarily on the basis of their stability and their ability to produce desired products. Mother culture is usually prepared daily from a previous mother culture and originally from the stock culture. The mother cultures can be used to inoculate a large quality of culture medium to produce the mass or bulk culture to be used in the fermentation process.

Bacterial cultures: Most of the bacterial cultures employed as starters are for dairy products. Sausage and bread also use pure or mixed cultures of lactic acid bacteria (LAB) e.g. *Streptococcus lactis* sub sp *lactis, S. mesenteroides* sub-sp. *cremoris* etc.

Yeast cultures: Most yeasts of industrial importance are of the genus *Saccharomyces*. It is used to manufacture wine, beer and other alcoholic products.

Bakers' yeast: Yeast for baker's yeast production: Strains of *S.cerevisiae, S.uvarum* are used.

Wine yeast: *S. cerevisiae var. ellipsoidus* (Plate 1.1)

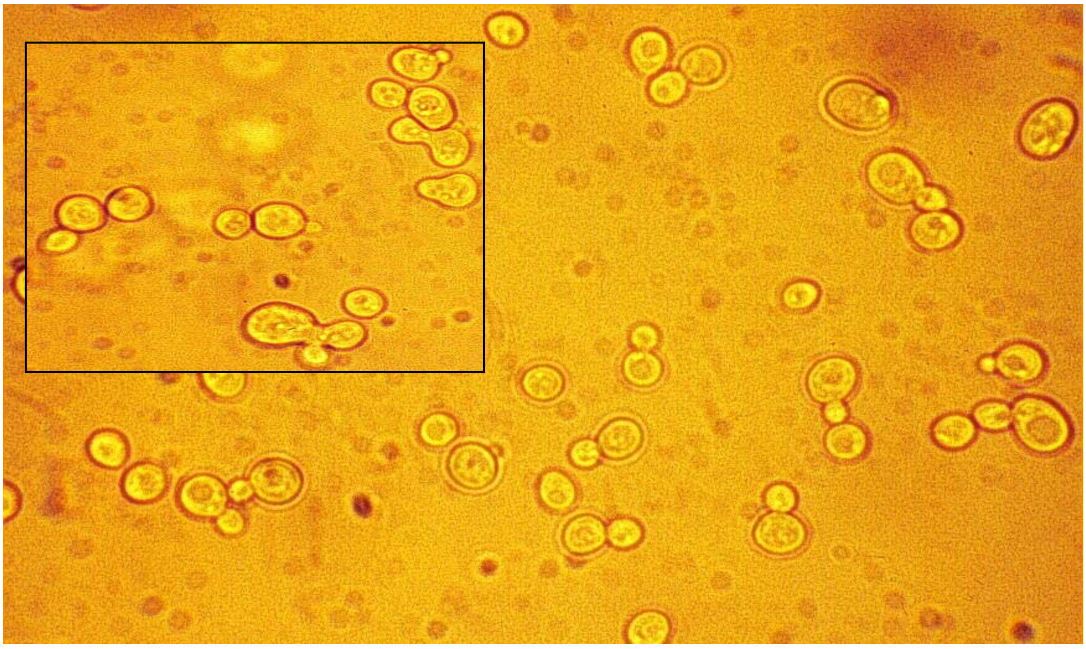

Plate 1.1: Photo micrograph of yeast cells showing budding (inset yeast cells are mating)

Distillers yeast: High alcohol yielding strains of *S.cerevisiae* var *ellipsoidus*.

Mold cultures: Stock of cultures of molds usually are carried in slants of a suitable agar medium and may be preserved as spore stab for a long period by freeze drying (*Penicillium roquefortii).*

3.3 ENZYMES AND KINETICS

Enzymes: Enzymes are biological catalysts possessing extraordinary efficiency, specificity and are mostly protein in nature. Enzyme commission has classified various enzymes on the basis of the type of the reactions catalysed. All the enzymes have been classified into 6 classes.

Class 1 : Oxido-reductase
Class 2 : Transferase
Class 3 : Hydrolase
Class 4 : Lyase
Class 5 : Isomerase
Class 6 : Ligase

Properties of Enzymes

- All enzymes are protein in nature except nucleases.
- All enzymes are specific in their functions.
- Enzymes are sensitive to temperature i.e. they are functional at optimal temperature.
- These are destroyed at higher temperature.
- Enzymes are not destroyed during their use.

Kinetics of Enzyme Reactions

The studies on the kinetics of enzyme reactions must be based on quantitative measurements of the rate of the catalyzed reactions. Main factors which influence the kinetics of enzymatic reactions are as follow:

Enzyme concentration: The velocity of enzymatic reactions is directly proportional to the concentration of the enzyme proteins.

Substrate concentration: When the velocity of the reaction is plotted vs. substrate concentration, classical enzymes give a rectangular curve.

pH: Almost every enzyme exhibits maximum activity at a particular pH which is called optimum pH.

Temperature: Almost every enzyme exhibits an optional temperature at which the enzyme exhibits maximal activity. A graph of enzyme velocity versus temperature, is a bell shaped curve.

Role of enzymes in food processing: The enzymes play a significant role in food processing. Pectinase enzymes are used in juice clarification (apple juice, guava juice), in softening of fruit (apple, tomatoes, peaches, avocadoes), and thereby resulting in increase in yield of juices and pulps extraction of juice from fruits. Proteases (papain) results in clarification and removal of cloudiness in beer and wine. Glucose oxidase enzyme is used in removal of glucose from egg white and thereby, improve, the colour of dehydrated egg powder. Pectinase with cellulase has been employed for extraction of oil from oil containing fruits (olive). Enzyme diastase converts starch to sugar during beer preparation.

3.4 TYPES OF FERMENTATION

Fermentations have been classified on the basis of relationship of the formation of product, substrate utilization or the free amount of water as given below:

Solid state fermentation: Fermentation processes which take place in the absence or near absence of free water in the substrate are termed as solid state fermentation (SSF). It is imperative, however, that the substrate contain enough moisture absorbed in the substrate particles within the substrate. SSF have been used mostly for food fermentation and production of a few enzymes.

Extractive fermentation: There are several industrially important products being catalysed by enzymes which are susceptible to end product or feedback inhibition. Hence, the increased concentration of the product inhibits the enzymes involved in its own synthesis so that the overall rate of conversion of substrate to the desired product is lowered. When the end product or anyone of the by-product of fermentation interacts with the enzyme, the synthesis of the final product proceeds sub-optimally and in extreme case may stop altogether. This problem has largely been overcome by using a technique called extractive fermentation. In it there is fast removal of product, or by-product of a metabolic pathway, so that their subsequent interference with the cellular or medium component is not possible. Hence, it involves all the actions taken for the separation of a product from its producing cell. Separation of the product can be achieved either inside the reactor (internal) or outside the reactor (external).

Submerged fermentation: Fermentation processes which take place in the presence of free water in the substrate are termed as sub-merged fermentation. Such fermentations have been used mostly to the produce fermented food and beverages.

3.5 TYPE OF FERMENTER, CONCEPT OF BATCH AND CONTINUOUS FERMENTATION

Fermenter: The industrial usage of micro-organisms often requires that they be grown in large vessels containing considerable quantities of nutritive media. These vessels are commonly called fermenters. Therefore, fermenter is the basic equipment of fermentation.

Types of fermenters: Some of the types of fermenter are listed below:

1. Shake flasks and bottles
2. Stirred tanks
3. Air-lift fermenters
4. Tower fermenter
5. Rotating disc fermenter
6. Fixed bed fermenter
7. Fluidized bed fermenter

Batch fermentation: In this fermentation, starter culture is added to the medium and the product is withdrawn only after completion of fermentation.

Continuous fermentation: In this fermentation, the substrate is continuously fed to the fermenter and the product is also withdrawn continuously.

3.6 MICROBIAL PRODUCTION OF WINE, VINEGAR, SAUERKRAUT, ETHYL ALCOHOL, BEER, ORGANIC ACID

3.6.1 Wines

The term ‘wine’ is applied to a beverage made by alcoholic fermentation of grape or grape juice and final production is obtained without distillation. But now-a-days, any fleshy fruit or flower in the new world may be employed for this purpose. Wine was suggested to have been made during the Neolithic period in the near East. These are the part of food of man ever since his settlement in Tigoris Euphorates basins and have also been used as a therapeutic agent.

Wines are produced by the fermentation of juices/extracts of many fruits such as apple, pear, cherries, most of berries, rhubarb, dandelion, honey, besides bananas, pineapple, cashew nut, pomegranate, lemons, tangerines, oranges, dates and figs. Wines from grapes are classified basically into red and white wines.

Types of Wines

Still wines: These wines retain none of the carbon dioxide produced during the fermentation.

Sparkling wines: These are the wines which have considerable amount of carbon dioxide. Champagne in France is the sparkling wine made in Champagne region.

Dry wines: These wines contain little or no unfermented sugar.

Sweet wines: Wines having either unfermented sugar or with added sugar later on are called sweet wines. Both types of wines generally contain 11 to 14% of alcohol.

Fortified wines: Wines to which distillate of wine called "Brandy" is added and may contain 15 to 21% of alcohol.

Table wines: It is a wine having comparatively low alcohol content (7 to 11%) and little or no sugar.

Sherry: It is produced by special processing technique from wine, containing 18 to 21% alcohol and could be sweet or dry.

Cider: Cider is a low alcoholic beverage obtained from apple by fermentation.

Perry: It is a wine made from pear juice.

Mead: This type of wine was prepared by the Indians from honey.

Vermouth: Wine flavoured with a characteristic mixture of herbs and spices, some of which impart an aromatic flavour and odour while others a bitter flavour. It can be sweet or dry with alcohol content of 15 to 21%.

Toddy: Sweet alcoholic drink, having alcohol content of 4-6%, is made by the fermentation of sap from coconut palm.

Pulque: National drink of Mexico, contains 6-7% alcohol and B-vitamins.

Method of Table Wine Preparation

Grape is the most widely used fruit to make wine but it can be prepared from any fruit having fermentable sugars, optimum acidity, nitrogenous compounds or other growth factors to make wine of acceptable quality. The major difference is in the extraction of sugar from the pulp of some fruits. From grape, red and white wines are produced the world over using black/red coloured and white varieties, respectively. The generalized flow sheets for wine making from grapes is shown in Figure 3.1.

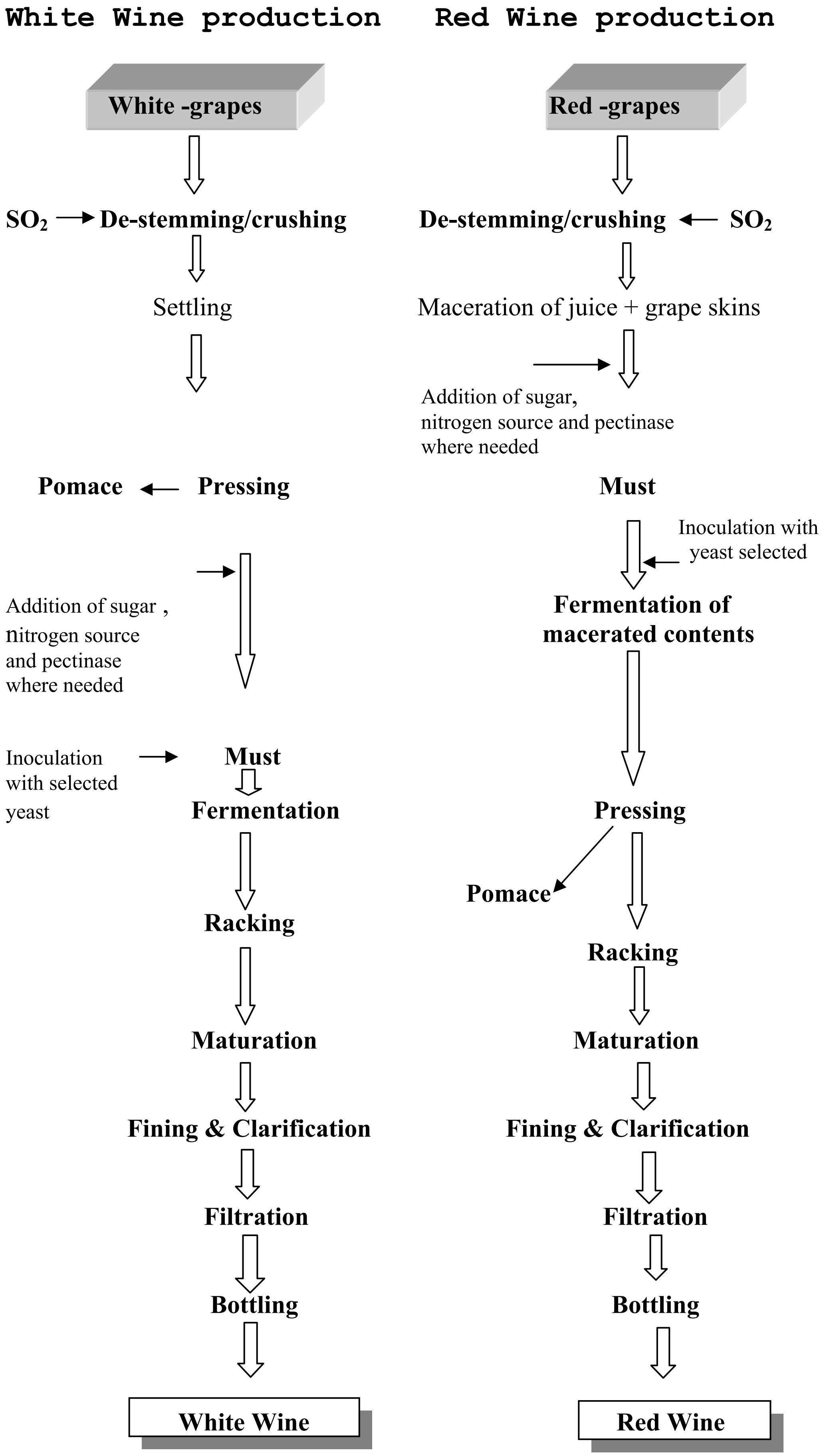

Figure 3.1: Flow–sheet of process to make red and white wine

Preparation of must: For wine preparation, the first step is the preparation of must which is prepared depending upon the type of fruits used and the type of wine to be made. Must is a juice or pulp corrected for sugar, acid/pH, nitrogen source or other requirements for the alcoholic fermentation. To prepare the must, the fruits are trimmed and washed and the must Juice is extracted or fruit is made into pulp. In the preparation of white wine only the free run juice is used while in the red wine, the skin and seeds along with pulp/juice are fermented together for some time to get attractive coloured wine. Proper dilution of fruit pulp is required as fruits like plum and apricot are highly acidic and effect the fermentability besides making the wine unpalatable. The sugar content of the juice or pulp is checked with an instrument called refractometer and is expressed as degree Brix. Sulphur dioxide ($S0_2$) is added to the must to control the wild microflora and to allow the yeast to act efficiently to conduct the alcoholic fermentation. Amelioration (or correction) of must for better fermentability with ammonium salt and vitamins like thiamine, biotin is necessary in some fruits.

Preparation of active yeast culture: An active culture of wine yeast (*Saccharomyces cerevisiae* var *ellipsoideus*) is prepared from the stock culture in the juice to be used for wine making.

Fermentation: After must preparation, activated yeast starter culture is added to the must and fermentation is carried out at a temperature of 20-25^{o}C, till the sugar content or the ^{o}Brix stabilizes.

Siphoning/racking

Siphoning or racking is a simple but important process wherein the wine is transferred through a clean pipe into another container, kept at a lower height than the vessel with wine. It is done after completion of fermentation. Two or three rackings are usually done at an interval of 15-20 days to separate the yeast and other settled materials at the bottoms of container.

Maturation

As the newly made wine is harsh and has yeasty flavour maturation (from 6 months upto a year) is allowed to make the wine mellow (It is the term used to signify the sensory quality of wine having smoothness i.e. is devoid of any harsh taste)in taste and fruity in flavour.

Clarification: Clarification of wine is done by using filter aids such as bentonite, celite and tannin/gelatin using a machine called filter press.

Blending: Blending is also practiced in some cases to make wine sweet or better flavoured before pasteurization.

Pasteurization: Wine is generally pasteurized at a temperature of 62^{0}C for 15-20 min, after bottling.

Storage: Low temperature storage is preferred for good quality wine.

3.6.2 Beer

Beer is an alcoholic beverage primarily prepared from barley besides other cereals in limited quantities and is consumed in large quantities throughout the world. Beer and ale the principal malt beverages made with hops, yeast, water and malt adjuncts. Adjuncts are the malted cereals other than barley, used in minor quantities. Brewing was one of the earliest processes undertaken on a commercial scale and became one of the first process that has developed from an art into a technology. Beer can be differentiated from ale as in beer bottom fermenting yeast is employed while in ale the top fermenting yeast is employed. In the preparation of ale, more hops is used. It is usually pale yellow in colour, tart in taste and have more alcohol content. On the basis of alcohol content beers can be classified as light beer having 3-5% v/v and hard beer having 5-8% alcohol content. Beer production is divided into four distinct process as described here.

Malting: It is obtained by soaking followed by germination of barley or other cereals and drying of the germinated cereal. Then, most of sprouts or germs are removed and the malt remains. The malt is crushed before its use in beer making.

Mashing: It is the process in which extraction of the ground malted barley with water is made. The mashing is done so as to make soluble as much as possible of the valuable constituents of the malt and malt adjuncts. It causes hydrolysis of starches, other polysaccharides and proteins. The insoluble material is then filtered. The liquid so obtained is called wort.

Wort boiling: Boiling of wort with hops (Hops is the female flowers of hops plant used in beer production to give flavour and bitter taste) is carried out to concentate the wort, inactivate the enzymes, extract soluble substances from the hops,coagulate and precipitate the proteins and other substances, caramelize sugar slightly and to contribute antiseptic substances (Chiefly the alpha resins humulone, co-humulone and adhumulone) to the wort and beer.

Fermentation: A special beer, bottom fermenting yeast strain *Saccharomyces cerevisiae* var *carlbergensis*, is used for the inoculation or pitching of the cooled wort. The wort temperature during the fermentation varies in different breweries but is usually in the range from 3.3 to 14^{o}C. The fermentation is usually completed within 8 to 14 days. During fermentation as the carbon dioxide is evolved in increasing amounts, the foaming increases; later it decreases to none when the fermentation is finished. At the later stage, the bottom yeast flocculates and settles down.

Aging or Maturation: The young, green or draft beer is stored or lagered in vats at about O^{o}C for several weeks to several months, during which period precipitation of proteins, settling of yeast, resin and other undesirable substances takes place and the beer becomes clear and mellowed or matured.

Finishing: After aging, the lager beer is carbonated to a CO_2 content of about 0.45 to 0.52 per cent, mostly by means of gas collected during the fermentation or by addition of CO_2 from cylinders. Then, beer is cooled, clarified or filtered and packaged in the bottles, cans or barrels.

3.6.3 Vinegar

The word vinegar is derived from two French words, *vin* and *aigre* meaning sour wine but the term is used to denote a condiment prepared from various sugar and starch containing materials by alcoholic and subsequent, acetic acid fermentation. It is one of the several fermented foods prepared and consumed by early man, even today. Earlier, it was used as a beverage, a condiment, a preservative, a household cleansing and medicinal agent. Vinegar mainly consists of a dilute solution of acetic acid in water, also contains colour, flavour and extracted substances besides fruit acids, esters and inorganic salts which vary according to its origin. The minimum legal strength for vinegar is 4% acetic acid (w/v).

Types and Composition of Vinegar

1. **Synthetic vinegar:** This type of vinegar is directly prepared from synthetic acetic acid with the addition of water and finally, it is coloured by caramel.
2. **Brewed vinegar:** Virtually, anything having enough sugar to produce alcohol can be used to make brewed vinegar. The vinegar usually derives its descriptive name from the material from which it is made such as: cider vinegar is made from apple juice, alegar from ale, malt vinegar from malted grains spirit vinegar from alcohol etc.

Vinegar Preparation

It involves two step fermentations as detailed below:

Alcoholic fermentation: The first is alcoholic fermentation, mainly carried out by yeast *Saccharomyces cerevisiae* either by pure culture inoculation or by the natural process of fermentation. The process can be represented by a simplified equation:

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5-OH + 55\ Kcal$$

Glucose   Carbon dioxide   Ethyl alcohol

In the process, ethyl alcohol is not the only product but small amounts of other compounds like glycerol, succinic acid, amyl alcohol, propyl alcohol etc. are also produced in this fermentation. The fermentation is anaerobic.

Acetous fermentation: The second fermentation is acetic acid fermentation. It is an oxidative fermentation carried out by acetic acid bacteria like *Acetobacter aceti*. In the vinegar production, pure culture of acetic acid bacteria is not used, due to more efficiency of mixed cultures. The oxidation reaction can be shown as:

$$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O + 116\ Kcal$$

Ethyl alcohol   Acetic acid

The optimum temperature of fermentation is 26^{o}C which is achieved by the heat generated in the process.

Process of Vinegar Preparation

Slow process: This process takes a long period and is generally followed in countries like India. The juice kept in the barrels is allowed to undergo alcoholic and acetic fermentations slowly with the passage of time. The bung hole of the barrel is covered with a piece of cloth to screen-off the dust and flies, and the barrel is placed in a damp but warm place. It takes about 5-6 months to complete the whole alcoholic and acetous fermentation to produce the vinegar from the juice. The main drawbacks of this process are: alcoholic fermentation is often incomplete, the acetic fermentation is very slow and the yield is low coupled with an inferior quality vinegar.

Quick process: In the quick process like generator process alcoholic liquid is in motion and this process is applied mostly to the production of vinegar from spirit (alcohol). Fruit or malt liquors are well supplemented with food for the vinegar bacteria, but to maintain active vinegar bacteria in generator methods using alcohol denatured with ethyl acetate or vinegar, it must be supplemented with a combination of organic and inorganic compounds known as vinegar food. Combinations of substances such as dibasic ammonium phosphate, urea, peptones, yeast extract, glucose, malt, starch, dextrin, salts etc have been made. Materials such as pumice, branches of vines and grape stems for packing the generators are used. Schiizenbach introduced the use of a vat instead of cask for the acetification process and provided mechanical means for the repeated distribution of the acidic liquid over the packing.

Generator: The equipment used is known as "Upright Generator" which in its simplest form is a cylindrical tank that comes in different sizes and is usually made of wood. Its interior is divided into 3 parts:

i) **Upper section:** Here, alcoholic liquid is introduced.

ii) **Large middle section:** In this section, liquid is allowed to trickle down over beech wood shavings, corn cobs, charcoal, coke, or some other material that will provide a large total surface area yet not settled into a compact mass.

iii) **Bottom section:** This section is for the vinegar collection.

The alcoholic liquid is put at the top through an automatic feed trough or a sprinkling device (sparger) and trickled down over the shavings or other material on which a slimy growth of acetic acid bacteria has been developed and the bacteria oxidize the alcohol to acetic acid and the process is called acetification. Air enters through the false bottom of the middle section and after becoming warm, it is exhausted out through a ventilation above. As considerable heat is released by oxidation process, it is necessary to control the temperature below 30^{o}C. It is usually done by using cooling coils, by adjusting the rate of alcoholic liquid, feeding air and by cooling the alcoholic liquid before it enters the generator or by cooling the partially acetified liquid that is returned to the top from the bottom section of the tank for further acetification.

3.6.4 Lactic Acid Bacteria (LAB) and Fermented Foods

Lactic acid bacteria (LAB) are obligate microorganisms producing lactate from sugars as the main end product, besides producing inhibitory substances like organic acids, bacteriocin, hydrogen peroxide which are antagonistic towards other microorganisms. Fermented dairy products are known to be inhibitory to both pathogenic and spoilage causing microorganisms and Yoghurt is the best known fermented milk product (with fruit pulp).Cultured milk and milk products contain lactic acid bacteria that prevent the occurrence of stomach, colon and other cancers.

Traditional fermentations of vegetables were depended upon growth of naturally occurring lactic acid bacteria to metabolise sugars in the vegetables to mainly lactic acid and improve their taste and keeping quality. However, starter cultures are being used now to develop controlled fermentation

It is established that more than one species of lactic acid bacteria are responsible for vegetable fermentation. Lactic acid bacteria responsible for natural fermentation of vegetables are within the genera of *Streptococcus*, *Leuconostoc, Pediococcus* and *Lactobacillus*. Acidity, pH, salt concentration, temperature, naturally occurring inhibitors, chemical additives, exposed brined surface to air and sunlight, amount of fermentable carbohydrates in the vegetables and availability of nutrients in the brine are important factors affecting the lactic fermentation.

Sauerkraut

It is the clean, sound product of characteristic flavour, obtained by full fermentation, chiefly lactic of properly prepared and shredded cabbage in the presence of not less than 2% nor more than 3% of salt. It contains, upon completion of the fermentation not less than 1.5 per cent of acid expressed as lactic acid. To prepare sauerkraut rough outer leaves of fully mature solid cabbage heads are removed. Head are quartered, the cores are removed and then, shredded the quarters into thin strips which are mixed with salt. About 2.25 to 2.5% of salt by weight should be added to the shredded cabbage to obtain kraut of the best quality. Pack the cabbage loosely in a jar, place a wooden board on the top. In order to press out juice from the cabbage, a heavy stone is placed on the wooden board. The jar is kept at a warm place (24 to 31^{o}C) for 8 to 12 days to allow fermentation to complete. The brine is separated from the cabbage, boiled and poured hot over the cabbage shreds in the jars. Sauerkraut can be packed in cans also. The cans are filled with the hot juice, exhausted and processed till the temperature at the centre of can reaches 82^{o}C.

Prominent bacteria that attain appreciable number early in fermentation are *Enterobacter cloacea* and *Erwinia herbicola* and contribute some flavour. However, *Leuconostoc mesenteroides* bacteria begins to outgrow all organisms and continue acid production upto 0.7 to 1% (as lactic acid). Next, *Lactobacillus plantarum*, a non-gas forming lactobacilli continues the production of acid and can raise the acidity to 1.5 to 2.0%. These bacteria produce chiefly lactic acid in their fermentation of sugars. A final acidity of 1.7% as lactic acid is most desirable and fermentation can be stopped at this stage by canning or refrigerating the sauerkraut.

Kanji

Carrots of deep purple variety are fermented in Northern India and Pakistan to make a ready-to-serve beverage /drink called as *Kanji.* It is a popular beverage and is considered to have cooling and smoothing properties besides nutritional content. To prepare it, the carrots are washed, grated finally. For every Kg of grated carrot, 7Kg of water, 200g of salt, 40 g of crushed mustard seeds and 8g of hot chillies are added followed by placing the mixture in a glazed earthenware, leaving a tiny whole for the release of gases produced during fermentation. The mixture is fermented for 7-10 days. It is strained through a muslin cloth. The final product is acidic in taste with an attractive purple red colour and is usually consumed within 3-4 days.

Pickles from Vegetables

Vegetables like cucumber are pickled whole or in slices after washing in potable water. For every one Kg of cucumber, 15g salt is added which results in the formation of brine. It is followed by lactic acid fermentation. Depending upon the ambient temperature it takes one to four weeks. The fermented cucumbers are stored in clean capped jars after pasteurization.

Radish can also be pickled in a manner similar to sauerkraut as discussed earlier.

Kimchi

It is a fermented food of Korea with cabbage or radish as the main ingredient. Cucumbers can also be added. Cabbages are cut and brined in 5 to 7% salt solution for 12 hr or in 15% brine for 3 to 7 hr. Then, brined cabbage is rinsed and mixed with 10% seasoning ingredients i.e. garlic, green onions, peppers, ginger, mustard, parseley, sesame grains and fermented shrimp. This mixture is allowed to ferment in jars which takes a few days at temperature of more than 20^{o}C for a month below 10^{o}C. 'Kimchi' has a pH value of 4-4.5 and lactic acid content of 0.4 to 0.8%. The main organisms responsible for fermentation of 'kimchi' are *Leuconostoc mesenteroides* and acidifying microorganism is *Lactobacillus plantarum*.

3.6.5 Ethanol Production

The material rich in sugar can be converted into ethanol. The fermentation is carried out using yeast like *Saccharomyces cerevisiae*. The sugars like glucose is converted into ethyl alcohol and carbon dioxide, anaerobically. Ethanol is a liquid fuel or liquid fuel supplement and is used as a solvent in many industries.

The waste from fruits and vegetable processing industries being rich in polysaccharides (cellulose, hemicellulose and lignin) has been subjected to SSF for the production of ethanol. The cellulose and hemicellulose present in the processing waste like apple pomace are readily fermented by anaerobic bacteria. For ethanol production, the waste from processing industries has to be pre-treated due to presence of lignin. A SSF process has been used for production of ethanol from apple pomace by using *Saccharomyces cerevisiae*. Apple, pear, orange peel and cherry wastes have also been utilized for production of ethanol by fermentation with *Saccharomyces cerevisiae*.

3.6.6 Enzyme Production

Both submerged fermentation (SF) and solid state fermentation (SSF) are employed for production of enzymes. But SSF is a better method than SF for production of enzymes. Various enzymes have been produced by fermenting food processing waste. Invertase enzyme by fermenting sauerkraut waste with the help of *Canidida utilis* has been produced. This enzyme is widely used in the food processing industry. Subsequently, fungal amylase by using baked bean waste has been produced. Enzymes like cellulase and xylanase are produced by fermenting apple pomace, using *Trichoderma viridae* and *Aspergillus* sp. Pectinase is another enzyme which is produced from wastes like apple pomace.

Table 3.3: Food processing waste used as SCP/animal feed after microbial fermentation

Waste	Microorganisms utilised
Apple pomace	*Saccharomyces cerevisiae* *Candida utilis* *Torula utilis* *Aspergillus niger*
Corn cob	*Aspergillus niger*
Dried citrus peel	*Aspergillus niger*
Fodder beets	*Saccharomyces cerevisiae*
Orange peel and grape stalks	*Pleurotus ostreatus* *Agrocybe aegirata* *Armillarialla mellea*
Sugarcane bagasse	*Polyporus* sp. *Pleurotus* *Trichoderma*
Sugar beet pulp	*Trichoderma reesei* *Tricoderma viridae* *Fusarium oxysporum*

3.6.7 Citric Acid

Citric acid is being produced by fermenting brewery waste with *Aspergillus niger*. Apple pomace is a potential source of citric acid when fermented with *Aspergillus niger* by SSF on various substrates like pineapple juice, molasses, sweet potatoes residue, sugar cane bagasse impregnated with pineapple juice, mandarin orange waste, apple pomace, grape pomace. While production of citric acid by fermenting apple pomace, addition of methanol to the medium increases the yield of citric acid.

3.7 SINGLE CELL PROTEINS

In developing countries like India, deficiency of proteins leads to mal-nutrition. It has necessitated to explore new non-conventional resources of protein production. Amongst the various processes used to supply protein are those based on the microbial growth and microbial biomass especially using the waste material (Table 3.3). Microbial cells used as proteins as single cell protein (SCP) and can be used as protein supplement for feed or food. A number of micro-organisms like yeast, fungi, algae and bacteria can be employed production of SCP and each of them has its advantage and disadvantages. The micro-organism in turn use these substances as starting materials for fermentation and SCP production by assimilation.

The SCP however, is not without limitations also such as high nucleic acids which are metabolized to uric acid and can give rise to articular gout in human beings. Secondly, human being can eat a maximum of 2.0g SCP/kg body weight/day in their diet. To overcome the nucleic acid levels in SCP various methods have been tried but with a variable success. The success of SCP depends upon economics of SCP production.

3.8 MICROBIAL FERMENTATION FOR UTILIZATION OF WASTE

With the advent of post-harvest technology, the fruits and vegetables are processed for the production of various products. The processing of fruits and vegetables in this way generate a large quantity of bio-degradable waste. The waste from processing of fruits and vegetables include water and various organic substances e.g. simple and complex polysaccharides (Sugars, starch, pectin, etc.), vitamins and minerals. The large quantities of waste generated in this way leads to environmental pollution. In today's environment conscious society, there are regulatory laws for the discharge of industrial effluent under the water conservation and control of Pollution Act 1974 and Environmental Protection Act, 1986 and these are mandatory for the processing industries. The waste from the processing industries can either be disposed-off after necessary treatment as per the directions of the pollution control agencies or it can be utilized by applying suitable technologies as illustrated in Table 3.4.

Table 3.4: Microbial utilization of food processing industry waste

Sl.	Products	Waste
1.	Ethanol	Citrus industry waste, apple pomace, peach waste, cashew apple pomace, pineapple waste, pear cutting.
2.	Biogas	Waste from fruit and vegetable industry as a whole, fermentation (wine and beer) waste.
3.	Single Cell	Apple pomace, peach waste, cashew apple proteins pomace, citrus waste extract, molasses, potato peels, cabbage waste.
4.	Cider, beer and vinegar	Apple pomace.
5.	Pectin	Citrus waste, apple pomace.
6.	Citric acid	Apple pomace.
7.	Baker's yeasts/ industrial yeast	Waste from wine, beer and distillary.
8.	Colour	Apple pomace.
9.	Flavours/Xanthan gum	Fruits and vegetable waste, citrus waste
10.	Animal feed	Apple pomace, peach waste, potato industry waste, olive processing waste.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define wine, toddy, vermouth, cider, beer and perry.

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2. What is lagering, pitching and draft beer?

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3. Name the yeast used in beer fermentation.

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4. What is role of boiling wort?

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5. Give various steps for wine and beer production.

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6. What is vinegar and SCP?

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7. Name the microorganisms and their sequence in lactic acid fermentation of cabbage.

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8. Name the processes used in vinegar preparation.

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9. Which is commercially available single cell protein source?

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10. Classify enzymes and their role in industry?

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11. Differentiate SF and SSF fermentation.

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12. Name the microorganisms associated with production of following products: Sauerkraut, Beer, Wine, Organic acid (acetic acid) and SCP.

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13. Define batch and continuous fermentation.

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14. Why yeast is preferred as a single cell protein compared to bacteria and algae?

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15. What are different types of fermenters? Enlist the same.

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16. Write 2-3 lines about the following:

Sauerkraut, Kimchi, vinegar

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3.9 LET US SUM UP

Fermentation is an ancient practice, carried out by natural or inoculated microflora. Several microorganisms are important as these are employed to produce the fermented food, additives and products of industrial significance. These include yeast, bacteria and fungi. Fermentation could be classified as solid state fermentation, submerged fermentation or extractive fermentation. Depending upon the mode of operation fermentation could be batch, fed batch or continuous type. At the industrial scale, the fermentationis carried outin the vessel called fermentor or bio reactors. Depending upon the type of fermentation or product, the type of fermentoris employed. Food fermentations include those to produce wine, beer, brandy, whisky, pickles, sauerkraut, kimchi, vinegar, yoghurt additives like citric acid, lactic acid, enzymes, ethanol, single cell proteins being produced commercially using microbial process.

3.10 KEY WORDS

Fermentation	:	was used for the production of wine but at present it encompasses the foods made by the application of microorganisms including lactic acid bacteria (LAB).
Bakers' yeast	:	The strains of *Saccharomyces uvarum* used to make bread.
Wine yeast	:	*S.* cerevisiae *var. ellipsoidus.*
Distillers yeast	:	High alcohol yielding strains of *S. cerevisiae* var *ellipsoidu* used to higher alcoholic beverages.
Controlled "starter" Culture	:	pure as well as mixed cultures of microorganisms are responsible for conducting fermentations, employed in the manufacture of certain food and dairy products such as fermented milk, butter, cheese, bread, malt beverages.
Enzymes	:	Enzymes are biological catalysts possessing efficiency and specificity and are mostly protein in nature.
Solid state fermentation	:	Fermentation processes which take place in the absence or near absence of free water in the substrate are termed as solid state fermentation (SSF).
Submerged fermentation	:	Fermentation processes which take place in the presence of free water in the substrate are termed as sub-merged fermentation.
Fermenter	:	The industrial usage of micro-organisms often requires that they be grown in large vessels containing considerable quantities of nutritive media. These vessels are commonly called fermenteors.
Wine	:	The term 'wine' is applied to the product made by the alcoholic fermentation of grape or grape juice. But any fleshy fruit or flower in the new world may be employed.
Beer	:	Beer is an alcoholic beverage prepared from barely or other cereals.
Vinegar	:	The word vinegar is derived from two French words, *vin* and *aigre* meaning sour wine but the term vinegar is used to denote a condiment prepared from various sugar and starch containing materials by alcoholic and subsequent, acetic fermentation.

Acetous fermentation : or acetic acid fermentation which is oxidative fermentation carried out by acetic acid bacteria viz. *Acetobacter aceti*.

Lactic acid bacteria (LAB) : These are the microorganisms that are obligate producing lactate from sugars as the main end product, besides producing inhibitory substances to other microorganisms.

Sauerkraut : It is the product of characteristic flavour, obtained by lactic fermentation of cabbage in the presence of 2-3% of salt.

Kimchi : It is a group of fermented vegetable foods of Korea with cabbage or radish as the main ingredient.

Single cell protein : The microbial biomass used as protein supplement for feed or food is called as single cell protein (SCP).

3.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

1. Your answer should include the following points:

   Wine: It is the product made by the alcoholic fermentation of grape or other fruit or flower.

   Cider: Cider is a low alcoholic beverage from apple juice.

   Vermouth: Wine flavoured with a characteristic mixture of herbs and spices, with an aromatic flavour and odour while others a bitter flavour, sweet or dry with alcohol content of 15 to 21%.

   Toddy: Sweet alcoholic drink, having alcohol content of 4-6%, made by the fermentation of sap from coconut palm.

2. Your answer should include the following points:

   Lagering: It is the process of storage of young, green or draft beer in vats at about O^{o}C for several weeks to several months, to make it clear and mellow.

   Pitching: It is the process of inoculation of yeast culture in the wort.

   Draft beer: The freshly prepared beer (not matured) is called draft beer.

3. Your answer should include the following points:

   The answer is *Saccharomyces cerevisiae* var *carlbergenesis.*

4. Your answer should include the following points:

   The boiling concentrates, sterilizes the wort and inactivates the enzymes.

5. Your answer should include the following points:

   Various steps are involved in beer production:

   Malting
   Mashing
   Wort boiling
   Fermentation
   Aging or Maturing
   Finishing
   Table wine
   Juice Extraction
   Must preparation
   Fermentation
   Siphoning/racking
   Maturation
   Clarification
   Blending
   Pasteurization

6. Your answer should include the following points:

   Vinegar: Vinegar is the product obtained by acetic acid fermentation of ethanolic liquid of any fruit and contains 3.75 %w/w acetic acid. It is prepared by alcoholic fermentation of fruit juice.

   SCP: Single cell proteins (SCP) are the microbial cells used as a source of proteins. To produce single cell proteins, suitable microorganism and medium is selected. The optimum conditions of growth are also determined and the same are given during the fermentation. The grown biomass is then harvested and the cells are used as a source of proteins.

7. Your answer should include the following points:

   First of all *Pediococus* comes, then *Streptococcus* followed by *Lactobacillus in* cabbage fermentation.

8. Your answer should include the following points:

   Slow process: This process takes long period wherein the juice is allowed to undergo alcoholic acetic fermentations. It takes about 5-6 months to complete the fermentation to form the vinegar from the juice.

   Quick process: In quick processes like generator process alcoholic liquid is kept in motion and this process is applied mostly to the production of vinegar from spirit (alcohol). The alcoholic fermented liquors is well supplemented with food for the vinegar bacteria, such as a combination of organic and inorganic compounds. The process needs additional supply of oxygen.

9. Your answer should include the following points:

   Spirullina which is used as a SCP commercially.

10. Your answer should include the following points:

    All the enzymes have been classified into six classes.

    Class 1 – Oxido-reductase e.g. dehydrogenases, peroxidases.

    Class 2 – Transferase

    Class 3 – Hydrolase

    Class 4 – Lyase

    Class 5 – Isomerase

    Class 6 – Ligase

    Uses of enzymes in food processing: Pectinase enzyme are used in clarification of juices (apple juice, guava juice), lemon juice etc. Pectinase enzyme result in softening of apple fruit, tomatoes, peaches, avocadoes and thereby resulted in increase in yield of juice and pulp during processing. Pectinase enzyme result in easy extraction of juice from fruits. Proteases resulted in clarification and removal of cloudiness in beer and wine. Glucose oxidase enzyme is used in removal of glucose from egg white and thereby, improve, the colour of dehydrated egg powder. Pectinase with cellulase enzymes are also used for extraction of oil from oil containing fruits. Beer cloudiness can be removed by use of proteases e.g. papain. Enzyme diastase resulted in conversion of starch to sugars during beer preparation.

11. Your answer should include the following points:

    The submerged fermentation (Smf) makes use of free liquid while in that of solid state fermentation (SSF) no free water is available.

12. Your answer should include the following points:

    The microorganisms used for the products are listed as below:

    Sauerkraut: Lactic acid bacteria

    Beer: *Saccharomyces cerevisiae* var *carbergenesis*

    Wine: *Saccharomyces cerevisiae* var *ellipsoideus*

    Organic acid (Acetic Acid): *Acetobacter aceti*

    SCP: *Spirullina, Saccharomyces cerevisiae, Candida utilis*

13. Your answer should include the following points:

    Batch fermentation: Here the starter culture is added to the medium and the product is withdrawn after completion of fermentation.

    Continuous fermentation: Here the substrate is continuously fed to the fermenter and the product is also withdrawn continuously.

14. Your answer should include the following points:

    1. Yeasts have nutritive value especially proteins and vitamins.

    2. Able to grow on a variety of carbon and nitrogen source.

3. Has faster growth and high yield, ability to grow at low pH.
4. Can grow on a large number of waste including that from processing industries.

15. Your answer should include the following points:

Types of Fermentors:

1. Shake flasks and bottles
2. Stirred tanks
3. Airlift fermenters
4. Tower fermenter
5. Rotating disc fermenter
6. Fixed bed fermenter
7. Fluidized bed fermenter

16. Your answer should include the following points:

Sauerkraut: It is the clean, sound product of characteristic flavour, obtained by full fermentation, chiefly lactic of properly prepared and shredded cabbage in the presence of not less than 2% nor more than 3% of salt.

Kimchi: It is a group of fermented vegetable foods of Korea with cabbage or radish as the main ingredient with or without cucumbers.

Vinegar: The word vinegar is derived from two French words,*vin* and *aigre* meaning sour wine but the term vinegar is used to denote a condiment prepared from various sugar and starch containing materials by alcoholic and subsequent, acetic fermentation.

3.12 SOME USEFUL BOOKS

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UNIT 4 SPOILAGE AND ASSOCIATED CHEMICAL/PHYSICAL CHANGES IN FOOD

Structure

4.0 OBJECTIVES

After reading this unit you should be able to:

- state the meaning of spoilage;
- principle of preservation of food;
- discuss various causes of spoilage;
- describe different types of spoilages; and
- preventive measures which should be taken.

4.1 INTRODUCTION

We all know that food is the basic necessity of all the living entities. Needless to say that such a commodity has to be absolutely safe and of highest possible quality especially free from toxins and spoilage. A food is said to be spoiled if it has been damaged or injured making it unsuitable for human use. "A product is fit as a food if a discriminating consumer, knowing the story of its production and seeing the material itself, will eat it, and conversely, the same product is spoiled when such an examiner refuses it as a food". All of us would agree that a food is spoiled if it is not harvested at proper maturity, is contaminated with dirt, handled by dirty or diseased person, is fertilized with sewage and has objectionable changes due to the activity of microorganisms or action of enzymes of the food. The major causes of spoilage are: the microorganisms or their enzymes, the native enzymes of food, rodents, environmental factors and purely chemical reactions.

It must be admitted that despite of the improvement in the methods of production, handling and processing, the microbiological quality still remains the most important factor. This aspect assumes significance from toxin production, spoilage of fresh and processed products and quality control and as sanitation indicators in a processing unit. Microbial quality is also on the top of the different hazards which are associated with the safety of food for consumption by human beings. Various fruits, vegetables and their products may be spoiled by one or more factors like unsuitable packaging, chemical changes or action of microorganisms, tissue enzymes, insects, rodents or improper methods of processing, under processing, etc. Different spoilage causing agents for various fruit and vegetable products, their prevention and health hazards associated with spoilage are also discussed here.

4.2 PRINCIPLES OF FOOD PRESERVATION

In accomplishing the preservation of food by various methods, three main principles are involved:

I. Delay or prevention of microbial decomposition of food
II. Delay or prevention of self-decomposition of food
III. Prevention of damage caused by insects, rodents, birds, mechanical causes etc.

Various principles and sub-principles of preservation of food are summarized in Table 4.1. First principle of food preservation is based mainly on the following considerations:

- By delaying the microbial decomposition of food
- By preventing the microbial decomposition of food

Most of the methods of food preservation depend not only on the destruction or removal of microorganisms but also on the delay in the initiation of their growth, and hindrance to growth once it has begun. Knowledge of growth curve of microorganisms is very helpful for developing the appropriate technique to delay the microbial decomposition of the food.

Table 4.1: Detailed principles of preservation

I. Delay or prevention of microbial decomposition of food

i) by keeping out microorganisms (asepsis).

ii) by removal of microorganism.

iii) by hindering the growth and activity of microorganisms.

iv) by killing the microorganisms.

II. Delay or prevention of self decomposition of food

i) by inactivation of food enzymes.

ii) by delay or prevention of purely chemical reactions.

III. Prevention of damage to food caused by insects, rodents, birds and mechanical causes

4.3 CLASSIFICATION OF FOODS BASED ON PERISHABILITY

1. *Perishable foods:* The foods which spoil readily unless special preservation methods are used such as meat, fish, most of fruits and vegetables, egg, poultry and milk etc.

2. *Semi-perishable foods:* Semi-perishable foods like waxed potatoes and some varieties of apple, if handled and stored properly, shall remain unspoiled for a fairly long period.

3. *Non-perishable foods:* These foods do not spoil until and unless they are handled carelessly. Such foods are also called as stable foods such as cereals, sugar.

4.4 FACTORS GOVERING SPOILAGE

Since microorganisms are the main spoilage causing factors, major emphasis remains on the factors related to microbial spoilage of the foods. Here bacteria cause most of the problems since these are not killed at ordinary temperatures. The yeasts and molds have low resistance to heat (processing temperatures). The main factors responsible for such spoilage are described here.

4.4.1 Number and Kind of Microorganisms

The initial number of microorganisms present on the food has direct relationship with its spoilage. More the number of microorganisms present, rapid is the spoilage. The effect of initial number of spores on time required to kill them is shown in Table 4.2. The heat resistance of bacteria involved in food poisoning is of major concern from public health view point. Usually, only one type of microorganisms will be there because of the particular environmental conditions involved. However, contamination may increase the number as well as new kinds of microorganims.

Table 4.2: Effect of initial number of spores on time required to kill them

Initial concentration of cells, number/ml	Thermal death time, or time required to kill all spores min. at 121°C
50,000	14
5,000	10
500	9
50	8

In addition to destruction or removal of microorganisms, the delay in the initiation of growth also prevents microbial spoilage. This is done by keeping the microorganisms in lag phase as long as possible. Once the microorganisms enter the log phase, it is very difficult to control them. A typical growth curve of microorganism is shown in Figure 4.1.

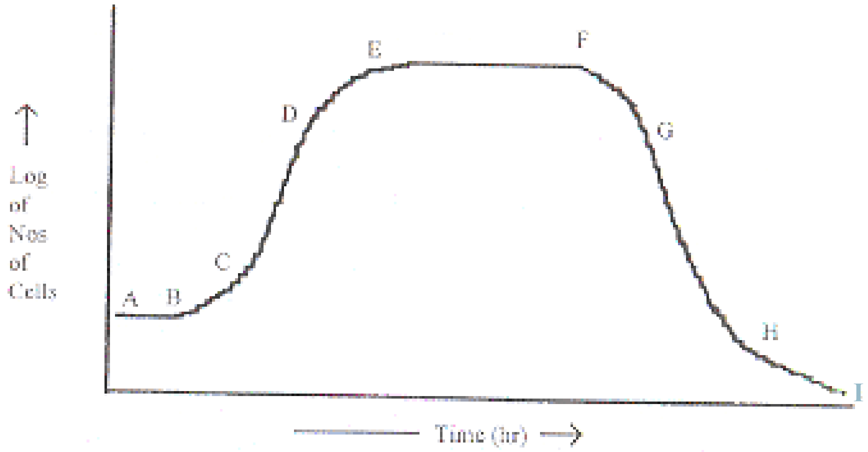

Figure 4.1: Growth curve of microorganism. A to B lag phase, B to C positive acceleration phase, C to D logarithmic phase, D to E negative acceleration phase, E to F stationary phase, F to G accelerated death phase, G to H death phase, H to I survival phase

4.4.2 Suitability of Temperature

Different microorganisms grow at different temperatures. Psychrophiles have affinity for low temperatures (8-10^{o}C), mesophiles grow best at medium temperatures (25-40^{o}C), while thermophiles appear at higher temperatures (50-55^{o}C). A large number of microorganisms grows at mesophilic temperature therefore processed foods are immediately cooled to arrest microbial activity / spoilage of foods. So, storage temperature is very important in relation to microbial growth and hence, the spoilage behaviour of foods.

Different types of microorganisms require different times to kill their cells or spores. The time required to kill all the spores of flat sour bacteria (*Bacillus stearothermophilus)* in relation to temperature is shown in Table 4.3.

Table 4.3: Effect of temperature of heating on the time needed to kill spores of flat sour bacteria

Temperature (^{o}C)	Thermal death time or time to destroy all spores, min.
100	1200
105	600
110	190
115	70
120	19
125	7
130	3
135	1

Source: Adapted from Frazier and Westhoff (1996).

4.4.3 Suitability of food

Different microorganisms prefer different kinds of foods. Some grow best on proteinacious foods, others on starchy or fatty foods. The physical state of the food whether heated, frozen, moistened or dried, also has an important influence on the spoilage it will undergo. The moisture content also influence the type of microorganisms in the foods since the requirements of moisture for their growth are different. Bacteria, yeast and molds have different moisture requirements in terms of water activity (Figure 4.2).

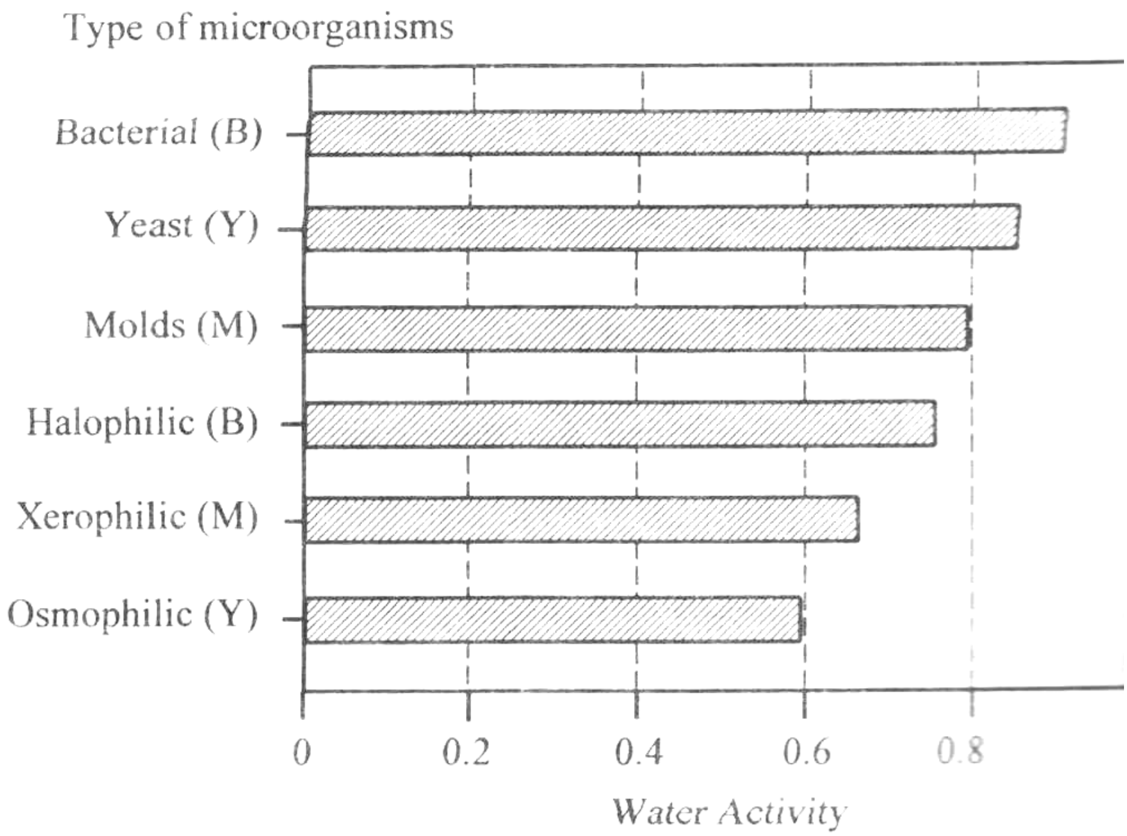

Figure 4.2: Water activity of different microorganisms

4.4.4 pH of Food

The pH of the food influences the kind and growth of microorganisms. The composition of the vegetable, its pH and moisture contents affect their type of spoilage. As a general rule, foods having pH<4.5 (acid foods) do not require heat processing (particularly cooking under pressure), but those with pH > 4.5 (low acid foods) always require processing under pressure.It is because of the reason that thermophilic bacteria may not be killed at normal temperatures as most bacteria thrive best at pH of 4-7.5, while the yeasts and molds require a pH of 2.5-8.0 and 1.5-8.5 for their growth.

4.4.5 Presence of Air

Aerobic or anaerobic microorganisms can be found in the spoiled fruit and vegetable products, depending upon the presence or absence of air (oxygen) in the container or package.

4.5 CHEMICAL AND PHYSICAL CHANGES ASSOCIATED WITH FOOD SPOILAGE

Changes in nitrogeneous organic compounds: Most of the nitrogen in the food present in the form of proteins which are hydrolysed by enzymes to produce amino acids. The anaerobic decomposition of the protein, peptide or amino acid results in the production of obnoxious odour which is called as putrefaction. When the microorganisms act on amino acid they deaminate or decarboxylate.

E. coli produces glyoxylic acid, acetic acid and ammonia from glycine and from serine it produces pyruvic acid and ammonia. Alanine is degraded into α-keto acid, ammonia and carbon dioxide by *E. coli*; acetic acid, ammonia, and CO_2 by *Psuedomonas*; and propionic acid, acetic acid, ammonia and CO_2 by. *Clostridium nigrificans*. Other nitrogenous compounds like amide, urea, guianidine and creatine, etc. are also decomposed to ammonia, carbon dioxide and other products.

Changes in Carbohydrates: Carbohydrates are preferred by the microorganisms as energy yielding foods. They hydrolyse the polysaccharides to monosaccharides before utilization such as to glucose which is then, oxidized to CO_2 and H_2O. Anaerobically, these undergo decomposition involving one or more types of fermentation.

- Alcoholic fermentation by yeast with ethanol and CO_2 as products.
- Lactic fermentation by homofermentative lactic acid bacteria with lactic acid or by heterofermentative lactic acid bacteria with lactic acid, acetic acid, ethanol, glycerol and CO_2 as chief products.
- Coliform type of fermentation by coliform bacteria with lactic acid, formic acid, ethanol, CO_2, hydrogen and perhaps aceton and butanediol as likely products.
- Propionic acid fermentation by propionoic bacteria producing propionic acid, acetic and succinic acid and CO_2.
- Butyric- butyric isopropyl fermentation by anaerobic bacteria producing butyric acid, acetic acid, CO_2, H_2 and in some cases, butylenes glycol, butanol and 2-propanol.

They are present as salts and are oxidized by the microorganisms to carbonate and cause the food medium to become alkaline. Organic acid aerobically are oxidized to carbon dioxide and water as is done by the film yeast.

Changes in other compounds: Other compounds also undergo changes as detailed here:

- Ethyl alcohol is oxidized to acetic acid.
- Glycoside is hydrolysed to sugars.
- Acetaldehyde is oxidized to acetic acid or reduced to ethanol.
- Protopectin are acted upon by pectinesterase – pectic acid + methanol (water soluble) by hydrolysis of methyl ester. Polygalacturonases destroys the linkage between galactouronic acid unit of pectin or pectic acid to yield smaller chain and ultimately, free D-galacturonic acid, which may be degraded to simple sugar.

Changes in Lipids: Fats present in the media are hydrolysed by lipase into glycerol and fatty acid.Phospholipids may be degraded to their constituents phosphate, glycerol, fatty acid, and nitrogenous base e.g. chlorine.

One or more such changes can be produced in the food undergoing spoilage. The physical and sensory qualities of the food also undergo changes, thus making the product unfit for human consumption.

4.6 MICROBIOLOGY OF FRESH FRUITS, VEGETABLES AND THEIR PRODUCTS

4.6.1 Spoilage of Fruits and Vegetables

In general, fruits and vegetables are bulky, easily damaged mechanically, consist largely of water which is readily lost and above all, are living entities and must be kept so for their longivity. Thus, they are sensitive to their environment viz., temperature, level of oxygen, carbon dioxide and ethylene etc. Spoilage of fresh fruits and vegetables usually occurs during storage and transport and while waiting to be processed into various products. These also get contaminated with spoilage organsims either from each other or when they are laid into the baskets, lugs, boxes etc. during harvesting. Mechanical injuries during transportation further aggravate the deterioration process. The decay of perishables may occur due to the physical factors, action of their own hydrolytic enzymes or microbial contaminants etc as discussed earlier. Since fruits and vegetables after picking are alive for certain time thus, are sensitive to their environment, their rate of metabolism is temperature dependent and they may be damaged by heat or cold or even by levels of different gases in the atmosphere. Oxygen is taken in during respiration and CO_2 heat and water vapours are given-off. As fruits or vegetables are detached from the mother plant, the continuity of the flow of sap is totally disrupted but the respiration and water loss continues leading to exhaustion of food reserve and moisture. The irreparable losses are caused leading to deterioration and eventually spoilage. Spoilage is mainly of 2 types: Abiotic spoilage and Biotic spoilage.

Abiotic spoilage: It is due to the different physical (wilting, caking and melting etc.) and chemical changes in the product (hydrolytic action of enzymes, oxidation of fats, putrefaction of proteins, browning reaction between proteins and sugars). Temperature control is the major factor to provide longevity to the fruits and vegetables.

Biotic spoilage: This includes the microbial action associated with bacteria, yeasts and molds on vegetables and fruits and the normal processes of aging. The species of microorganisms causing food spoilage largely depend upon different factors e.g. kind and variety of fruits/vegetables, environmental condition e.g. storage, temperature, relative humidity of the atmosphere and various gas contents of the atmosphere etc. There are two types of microbial spoilage: (a) Spoilage caused by plant pathogens which attack various parts of the plant used as foods, (b) Spoilage caused by saprophytes. The most common and general type of spoilage in fruits and vegetables are mildew are listed in Table 4.4. Dry rots often lead to darkening and discoloring, and hardening of the surface of vegetables and fruits. In microbial spoilage, the vegetables often develop water soaked musky areas while the fruits generally have brown or white colored patches.

Table 4.4: The chief market diseases of some vegetables and fruits

Item	Market diseases
Onions	Bacterial soft rot, black mold rot, gray mold rot
Garlic	Bacterial soft rot, black mold rot
Green beans	Bacterial soft rot, mold rot, *Rhizopus*
Carrots	Bacterial soft rot, black rot, *Fusarium* rot, gray mold rot, watery soft rot
Beets	Bacterial soft rot, black rot, blue mold rot, *Fusarium* rot
Lemons	*Alternaria* rot, anthracnose, blue mold rots, stem-end rots
Peaches	*Alternaria* (or green mold rot), gray mold rot, black mold rot
Apricots	Blue mold rot, brown rot, *Cladosporium* rot, *Rhizopus* rot
Bananas	*Anthracnose, Fusarium, Gleoporium, Pestalozia*
Grapes	Black mold rot, gray mold rot, *Rhizopus* rot, blue mold rot
Strawberries	Gray mold rot, leather rot (*Phytophthora cactorum*) *Rhizopus* rot
Pears	Black rot, blue mold rot, brown rot, gray mold, *Rhizopus* rot
Potatoes	*Fusarium* tuber rot, bacterial ring rot, bacterial soft rot
Cucumber	*Rhizopus* soft rot, bacterial soft rot, blue mold rot, gray mold rot
Cabbage	Bacterial soft rot, gray mold rot, black rot, watery soft rot
Cauliflower	Bacterial soft rot, gray mold rot, black rot, watery soft rot
Tomatoes	*Alternaria* rot, bacterial canker, bacterial spot, gray mold rot, green mold rot, *Rhizopus* rot

The composition of the fruit/vegetable, its pH and moisture content affect their type of spoilage. Moisture content is usually expressed in terms of water activity ‘aw’. Various microorganisms have different requirements for moisture level (Figure 4.2). Amongst the microorganisms, spoilage can be caused by bacteria, molds/yeasts etc. depending upon the pH of food.

Bacteria: Various groups of bacteria can attack different fruits and vegetables, depending upon their composition such as lactic acid bacteria, acetic acid bacteria, coliform bacteria and sporeforming bacteria. The food can be preserved for longer time by prolonging the lag phase. This can be obtained by avoiding the contamination of the food and turning the environmental conditions e.g. temperature, moisture and pH unfavourable for the growth of contaminants (microorganism). Thus, by lowering the storage temperature of the fruits/vegetables, filling up the storage chamber with the inert gases will definitely lead to longer shelf- life of the vegetables and fruits. pH is another important factor governing the bacterial growth which range between pH 4-8. Growth rate is lowered by a decrease in pH.

Yeasts: Yeasts are widely found in the environment. The yeast growth depends largely upon the nature of fruit product. These are generally fermentative in nature.

Molds: Molds are frequently associated with food products. Some of the molds secrete toxic compounds (mycotoxins) like aflatoxins, patulin etc. Aflatoxin has been detected in dried figs and fig paste while patulin is the most common mycotoxin detected in the processed fruits. The mold *Penicillium expansum* which causes apple rot and some other molds produce patulin. The mycotoxins are deleterious to various animals and presumably the human beings also.

4.7 SPOILAGE OF PROCESSED FRUIT AND VEGETABLE PRODUCTS

The spoilage of processed fruit and vegetable products is also of two types: Abiotic spoilage and Biotic spoilage.

a) **Abiotic spoilage:** It is due to the different physical and chemical changes in the product viz. putrification of proteins, browning reactions between sugars and proteins and the physical changes of colour, caking and melting etc. The temperature and humidity are the main factors responsible for causing this type of spoilage. There is a relationship between moisture content and relative humidity with respect to different causes of spoilage in food products.

b) **Biotic spoilage:** It includes the actions associated with microorganisms, damage caused by insects, rodents etc.

Manifestation of spoilage: The microbial deterioration of a processed food product usually is manifested by alterations in the appearance, texture, colour, odour, flavour or slime formation. The appearance includes colour changes, visible growth of microorganisms, formation of pockets of gas or swelling of cans and microbial growth especially that of molds on the surface of food process (Plate 4.1). As some food products deteriorate, they tend to become soft or mushy. Degradation of foods results in the formation of compounds which have odours and flavours different from those of the fresh food.

Plate 4.1: Different spoiled products from fruits and vegetables. 1) Mold growth on pickle, 2) Mold growth on jam, 3) Mold growth on juice, 4) Mold growth on tomato crush, 5) Puffed can

Spoilage of Canned Fruits and Vegetables

Like other foods, canned fruit and vegetable products are also liable for spoilage for various reasons. Number of microorganisms surviving the heat process, storage temperature, suitability of the canned food to support the growth of the microorganisms, pH of the food, oxygen tension etc. may affect the spoilage of canned foods. Broadly, there are four causes for the spoilage of canned fruit and vegetable products viz., microbiological, physical, chemical and miscellaneous.

Microbiological spoilage: The spoilage caused by the growth of different kinds of microorganisms may be affected by under processing, inadequate cooling, infection resulting from leakage and pre-processing spoilage.

Under processing: Insufficient or improper heat treatment may result in survival of certain microorganisms causing spoilage of food product during subsequent storage. Some lot or a part of the lot may remain under processed or not processed at all (gross under processing) by mistake. As a general rule, only one type of microorganisms (bacteria or yeast or mold) are involved in such spoilage. Most of these are facultative anaerobes unusually heat resistant spore formers. Faulty operation during processing may also cause under processing. This type of spoilage can be avoided by ensuring proper heat transfer, proper retorting and proper stacking of cans in the retort.

Inadequate cooling: Immediately after processing, the cans are cooled using cold water. It gives a sort of shock to the surviving microorganisms and kills them. It also checks overcooking and hence, saves the food from textural disintegration. If cooling is not proper, spoilage can occur. In addition, the cans are cooled down (using fans also) upto 35-38°C only to allow the water to evaporate readily from the can surface. It will check the rusting of cans during storage, which may otherwise lead to some spoilage. It can be avoided by proper cooling after processing.

Infection due to leakage: Post-processing contamination may take place if there is leakage in the cans due to faulty seam, faulty lock seam or pinholes due to corrosion from inside of the can or rusting of can from outside. Here all the types of microorganisms can be present in the food. Lot of oxygen can enter into the can. Contents of such type of cans are not suitable for consumption. To avoid such kinds of spoilage, seam tests should be carried out regularly while in operation, proper hygiene should be maintained and handling should be proper. The cooling water should be chlorinated using 5-7 ppm of chlorine.

Pre-process spoilage: If the raw material is already heavily contaminated many microorganims may survive heat treatment and also the finished product may not be of desirable flavour or quality. It may also be due to faulty procedure during washing (of raw materials, cans and equipment) blanching and filling of cans. Many respiratory gases can develop causing swelling of cans during storage. To avoid such type of spoilage, proper testing of raw materials, proper washing of raw material as well as equipment, chlorination of water and proper sterilization of cans should be practiced.

Thermophillic spore forming anaerobic spoilage: The microbiological spoilage of canned fruits and vegetables can be of different types.

Flat sour: It derives its name from the fact that the ends of the can of food remain flat but the contents become sour. It is mostly found in non-acid foods like canned vegetables by the action of microorganisms (flat sour bacteria). So it cannot be detected without opening of can and culturing the microorganisms. *Bacillus stearothermophilus* and *Bacillus coagulans* are the thermophilic spore-forming bacteria responsible for flat sour type of spoilage. The latter are found in tomato juices. The immediate source of the flat sour bacteria is usually the plant equipment besides sugar, starch or soil.

TA spoilage: It is the short name for spoilage caused by thermophilic anaerobes which do not produce H_2S e.g. *Clostridium thermosaccharolyticum*. It is a sugar-splitting obligate thermophilic, sporeforming anaerobe which produces CO_2 and H_2, causing the swell and even bursting of cans. The spoiled food usually have sour odour and the source of contamination could be the plant equipment, sugar, starch and soil similar to that of flat source.

Sulphide or Sulphur Stinker spoilage: Such spoilage is caused by *Clostridium nigrificans*, mostly found in low acid foods like peas and corn. The spores of this bacterium are considerably less heat resistant and hence, their appearance in canned foods is indicative of gross under processing. H_2S can be detected by its characteristic odour on opening the can and the organism can also be detected in the form of black (FeS) colonies formed on iron sulphite agar at 55^{o}C.In case of peas, it is difficult to detect any marked discolouration. The source of this organism includes sugar, starch, soil, manure and the plant equipment.

Mesophilic spoilages: Some species of *Bacillus* and *Clostridium*, non-spore forming bacteria and even yeasts or molds may spoil the under-processed canned foods. The spore forming mesophilic thermoduric species of bacteria include *C. pasteurianum, C. butyricum, C. botulinum, C. sporogenes, B. sublitis, B. polymyxa,* etc. The non-spore forming mesophilic bacteria involved in the spoilage of tomato products, pears and some other fruits were found to be *Lactobacillus* and *Leuconostoc*. Other such genera may be *Pseudomonas*, *Micrococcus*, *Flavobacterium* etc. which may come from water and leaks in the cans.

Spoilage by yeasts: The yeasts have been found to spoil canned fruits, jams, jellies, fruit juices, etc. underleakage or under-processing conditions. Film yeasts like *Candida, Pichia*, *Hansenula* can grow on acid products like saurkraut and pickles osmophilic yeasts like *Saccharomyces rouxi*, *S. mellis* can spoil dry fruits, concentrated fruit juices and honey etc. Salt tolerant yeasts like *Torulopsis* and *Brettanomyces* can grow in brine solution.

Spoilage by molds: The molds are the common spoilage organisms of home canned foods like jams, jellies, marmalades. The common one are *Aspergillus, Penicillium, Byssochlamys fulva* etc.

Spoilage by physical causes: Some physical deformation of the container can lead to spoilage. Faulty technique in operation, under exhausting, over filling and panelling or buckling of the cans can cause spoilage of processed food products.

Faulty technique in operation: Just after retorting, if the pressure is released at once instead of slow release, distortion of can body can occur. Joints or seams may be distorted resulting in leakage. To avoid such kind of spoilage, the pressure in the retort should be released slowly after retorting and standard iron plates should be used for cans.

Under-exhausting: If the air entrapped in the tissues of canned fruit and vegetables, and the filling medium is not expelled properly, adequate vacuum may not develop which may consequently, impair the quality and appearance of the product.

Over-filling: Over-filling of cans does not allow proper vacuum formation after processing. It may also lead to flipper or springer type of spoilage. The proper filling is essential to avoid this defect.

Panelling or buckling: It occurs in case of big sized cans. If there is very high vacuum inside the can, atmospheric pressure can struck or force the can inwards resulting in leakage type of spoilage. To check such spoilage, proper vacuum should be created in the cans carefully.

Chemical spoilage: It includes reactions among ingredients, reactions between can and ingredients, hydrogen swell etc. Mainly, it is due to H_2S production, presence of oxygen, acids etc. H_2S is formed by the action of SO_2 (added through sugar or by decomposition of proteins) and H_2 formed by fruit acid acting on tin plate. If there is sufficient vacuum, H_2 is absorbed after storage for long time. Low acid foods have more H_2 swells. Therefore, pH of the food has important role in checking such spoilages. If the pH is near 4.0, it is favourable for many chemical reactions. To avoid the spoilage, we can assure proper vacuum (by hot filling) in the can and also adjust safe pH of the food prior to canning. Rusting and corrosion and perforation of tin plates: After cooling the processed cans in water, if some water remain on the surface of cans, rusting can take place. Similarly, the hygroscopic nature of the labels can also add to the rusting. In case of acid foods, there are more chances of corrosion and perforation of tin plates. More the oxygen in the can, more is the corrosion. Corrosion is more at higher than at lower temperatures. To avoid corrosion and perforation of tin plates, proper exhausting should be done and cans should not be cooled below 35^{o}C in water or fans should be used to evaporate water from the can body and non- hygroscopic in nature labels should be used and be stored at relatively low temperatures.

Metallic contamination: The tannins of raw materials or spices used react with exposed iron of the tin plate to form ferric tannate, a black product. Similarly, the SO_2 on reacting with H_2 forms H_2S that may further react with iron content of the can to form iron sulphide thus, causing spoilage of the processed food product. Also, on using the equipment made of copper or brass after sometime, in spite of thoroughly cleaning, small traces of copper oxide may remain there, which further form black copper sulphide on reacting with H_2S and discolour the product. To avoid such spoilage, proper exhausting and proper selection of equipment, thorough washing of the raw material as well as equipment.

External Appearance of Can

Flipper: A can with mild positive pressure is called a flipper. It may be an initial stage of swell or hydrogen swell but more frequently, it is due to over-filling or under exhausting, leakage or sealing at low temperature. The can ends remain flat but when the sides of can are struck with some hard structure or if the temperature of the contents is increased, bulging of ends take place.

Springer: A mild swell at one or both ends of a can is called a springer. One end may also remain permanently bulged and other flat. Pressure on the bulged end will bring it to normal but it will go to other end. Generally, the food in such cans remains fit for consumption. The reasons are similar as for flipper can.

Swells: In this case, both ends remain bulged. It may be a soft swell or hard swell. In case of soft swell, the ends are not so hard. On applying some pressure, the ends may go inward (normal) but do not remain normal on the removal of pressure. Obviously, in hard swell, can ends are rigidly hard and there is no effect of pressure except bursting or leakage of the can. The swell occurs due to the production of H_2 (formed by action of acids of food and tin plate), CO_2 or other gases (as a result of decomposition of contents by microorganisms) involving both thermophiles or mesophiles. The food is not fit for consumption and may even contain toxins produced by *Clostridium botulinum*.

Leaker: A very small leak may appear in the can due to faulty seam, faulty lock seam or pinholes resulting from corrosion from inside of the can or rusting of the can from outside.

Breather: Tiny leak in the can may allow air to pass back and forth into the can but not the microorganisms. The inside pressure of the can equals outside pressure. The contents may be spoiled due to rusting of can caused by oxygen in air passing through the tiny leak.

Buckled cans: Sometimes, the vacuum in big sized cans is so high that atmospheric pressure can strike the can body resulting in deformation of can leading to leakage of contents or contamination.

Spoilage of Fruit and Vegetable Juices

Fruit juice/squashes: The fruit juices are more spoiled by yeasts and molds than by bacteria since they have lower pH while vegetable juices are spoiled more by bacteria than yeasts and molds because of very high pH. If the fruit and vegetable juices are not processed after extraction, they are spoiled because of enzymatic changes and microbial actions. Apple and grape juices are spoiled by bacteria if the temperature of storage goes above 25^{o}C. Molds can grow on the surface of fruit juices if exposed to air. Most fruit juices have sufficient sugar to favour the growth of yeasts. Deficiency of B group vitamins discourages some bacteria. Concentrates of fruit and vegetable juices favour the growth of yeasts and of acid bacteria and sugar tolerant (*Zygosacharomyces)* species because of increased acidity and sugar concentration. Fruit juice concentrates are fermented almost exclusively by *Saccharomyces rouxi*, *S. mellis*, *Torulopsis* and *Hansenula*. Typical fermentation products are ethanol and CO_2. Heat treatment during canning of these concentrates usually kills these microorganisms and freezing prevents the growth of such organisms. In fruit squashes, if presevatives are not added in proper concentration, some yeasts (e.g. *Zygosaccharomyces*) can spoil such products.

Spoilage of canned fruit juices: The acidity is the single most important factor affecting microbial spoilage of fruit juices. Most bacteria have an optimum pH near 6.8 but may grow at pH values ranging from 4-8. Yeasts and molds can grow at pH <2.

In canned foods, a pH of 4.5 is used as a borderline between acid and low acid foods, that is foods not requiring and those requiring respectively, the minimum botulinum cook (12 D). The typical spoilage flora of fruit juices is represented by some Clostridia, *Bacillus*, members of Enterobacteriaceae, lactic acid bacteria, *Acetobacteriaceae*, yeasts and molds. The spoilage is characterised by lowering of pH (0.2-0.4 units), development of very high volumes of hydrogen and CO_2, and strong cheesy (butyric) odour. Three types of Bacilli are usually involved in spoilage of fruit juices i.e. *B.coagulans* (flat sour), *B. macerans* and *B. polymyxa* (both by storage at temperature < 46^{o}C).

The spoilage by enterobacteriaceae is characterised by the production of lactic acid, acetic acid, formic acid, H_2 and CO_2. Lactic acid bacteria causing spoilage of fruit juices include *Lactobacillus, (L. plantarum, L. fermenti) Leuconostoc mesenteroides, Streptococcus viscosum*. Among the yeasts, the most often involved species in juice fermentation belong to *Saccharomyces, Torulopsis, Candida, Pichia, Hansenula* and *Hanseniaspora.*

Molds require O_2 for development and so usually do not grow at the surface of processed fruit products. However, *Byssochlamys fulva* and *Penicillium expansum*, have been found in canned foods and the latter can grow under vacuum also.

Carbonated beverages are usually not spoiled because of inhibitory effect of CO_2 on microorganisms. The acidity (resulting from carbonation and addition of acids) also inhibits microorganisms. Since molds require air, they do not grow on the carbonated beverages.

Spoilage of Jams, Jellies, Marmalades and Preserves

Jams and jellies have usually low water activity (0.75-0.86). In addition, due to added acid, the pH is lowered and sometimes may have preservatives such as benzoic acid. All these factors lower down the risk of spoilage. Also due to heating, spoilage causing organisms (yeasts, molds) are eliminated until the package is opened whereupon recontamination could be expected (Plate 1).

Usually, osmophilic yeasts such as *Torulopsis*, *Xeromyces* and many other have been reported to spoil jams, jellies and preserves.

Spoilage of Frozen Fruits

Many fruits and fruit products are preserved by freezing including cherries, fruit juice concentrates, purees (^{o}B>45) and some sliced fruits. Usually, dry sugar or syrup is added to fruit prior to freezing. The predominant microorganisms are usually yeasts and molds besides lactic acid bacteria (in orange juice concentrate).

Spoilage of Dried Fruits and Vegetables

In dried fruits (apples, apricots, dates, figs, peaches, prunes, resins etc.), a number of microorganisms can be expected. Due to decreased water activity (<0.65 in case of sun dried products), heat treatment during dehydration and fumigation, the microorganisms may be killed or unable to cause spoilage. But, spores of bacteria and molds are likely to be the most numerous. Dried fruits may be spoiled due to the development of rancidity as concentrated flavonoids may undergo oxidation. Dried or partially dried fruits (dates, figs and prunes) are also susceptible to yeast spoilage i.e. *Zygosaccharomyces*.

4.8 PREVENTIVE MEASURES

While the fresh fruits and vegetables are spoiled by biological (microbiological) and non-biological causes, their spoilage is checked by adopting suitable preservative techniques. But the processed products do not normally spoil unless the preservative technique applied is not proper or is not applied properly or the product is stored improperly. There are a few generalized preventive measures which can be adopted to avoid their spoilage.

- It is desirable to keep the initial microbial contamination as low as possible. The commodities should be handled and stored to avoid further contamination and create conditions to check the growth of microorganisms.
- All efforts be made to apply the preservative technique, keeping in view the various steps to avoid spoilage.
- Mechanical disruption of the processed product tissue should be prevented. Equipments used for handling should be clean and free from contamination and contamination from the soil microflora should be avoided. Dipping of fruits and vegetables in solution of chlorine (50-125 ppm) removes the adhering microflora.
- Inhibition of microbial growth can be achieved by storing the food at low temperature or in inert atmosphere packaging.
- While packaging the processed product, it is absolutely essential that the environment of packing should be microbes free or least contaminated and away from stores to minimize the post-processing contamination.
- The chemical and microbiological quality of water is the single most factor which can control the quality of the finished processed product. It should conform to the prescribed standards of microbiological (indicator microorganism) and chemical quality.

- The spoilage of canned products can be minimized especially leakage by regularly checking the equipments used in canning (reformers, flanger, double seamer, retort).
- The quality of raw material is controllable factor which have profound influence on the spoilage behaviour of processed product.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why the food can get spoiled?

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2. List various causes of spoilage of food?

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3. Enumerate various principles used in preserving food?

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4. What are the major causes of spoilage of canned fruits and vegetable?

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5. Can dehydrated fruits and vegetables also get spoiled if so why?

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6. What is meant by acetification, putrefaction, rancidity, fermentation?

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7. What is meant by hard swell, Hydrgen swell and flat sour?

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8. What is meant by water activity?

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9. Can jams be spoiled?

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10. Name a few microorganisms involved in spoilage of juices.

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11. Can the carbonated juices also get spoiled? If so how?

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12. Enumerate various factors responsible for microbial spoilage.

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13. How would you classify the foods based on perishability?

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14. Classify the microorganisms according to their optimum temperature of growth?

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15. Name the bacterium responsible for causing flat sour.

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16. What is the relationship of initial number of microorganism with spoilage?

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17. Enlist five ways the spoilage can be prevented.

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4.9 LET US SUM UP

The foods especially fruits and vegetable are a living commodities and are therefore, liable for spoilage. The nature and kind of spoilage, however, depend upon the type of food and the environment where it is kept or how it is handled and stored. The causes of spoilage include contamination with microorganisms, activity of microorganisms or their enzymes, activity of native enzymes of food, infestation with rodents and influence of various external conditions where the food is stored. Decomposition of food constituents such as proteins, fats and carbohydrates and their interactions result into production of chemicals with different quality and hence, not acceptable as a food. To prevent spoilage, the foods are preserved either by giving low temperature during storage, or heated in appropriate media, irradiated, dehydrated or preserved with chemicals or made into fermented products. If such methods are not properly employed the foods can get spoiled even when they are processed.

4.10 KEY WORDS

Spoiled food : A food is said to be spoiled if it has been damaged or injured making it unsuitable for human use.

Perishable foods : There are the foods which spoil readily unless special preservation methods are used such as meat, fish, most of fruits and vegetables, egg, poultry and milk etc.

Non-perishable or stable foods : These foods do not spoil until and unless they are handled carelessly such as cereals, sugar etc.

Putrefaction : The anaerobic decomposition of the protein, peptide or amino acid resulting in the production of obnoxious odour is called as putrefaction.

Psychrophiles : Those microorganisms which have affinity for low temperatures (8-10^{o}C).

Mesophiles : Are the microorganisms which grow best at medium temperatures (25-40^{o}C).

Thermophiles : These microorganisms appear at higher temperatures (50-55^{o}C).

Under processing : It denotes insufficient or improper heat treatment that may result in survival of certain microorganisms causing spoilage of food product during their subsequent storage.

Water activity (aw) : Moisture content is usually expressed in terms of water activity.

Under-exhausting : If the air entrapped in the tissues of canned fruit and vegetables and the filling medium is not expelled properly, is called under-exhausting.

Panelling or buckling	:	It occurs in case of big sized cans when there is very high vacuum inside the can, atmospheric pressure can struck or force the can inwards resulting in leakage type of spoilage.
Flipper	:	A can with mild positive pressure is called a flipper.
Springer	:	A mild swell at one or both ends of a can is called a springer. One end may also remain permanently bulged and other flat.
Swells	:	In this case, both ends remain bulged. It may be a soft swell or hard swell.
Leaker	:	A can with a very small leak due to faulty seam, faulty lock seam or pinholes resulting from corrosion from inside of the can or rusting of the can from outside is called leaker.
Breather	:	It denotes tiny leak in the can that may allow air to pass back and forth into the can but not the microorganisms. The inside pressure equals outside pressure.
Buckled cans	:	Sometimes, the vacuum in big sized cans is so high that atmospheric pressure can strike the can body resulting in deformation of can which may further cause leakage of contents or contamination.

4.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

1. Your answer should include the following points:

   A food is a living commodity and respire and undergo various metabolic changes which if unchecked can spoil the food or if it is not harvested at proper maturity, is contaminated with dirt, or the microorganisms.

2. Your answer should include the following points:

   The major causes of spoilage are: the microorganisms or their enzymes, the native enzymes of food, rodents, environmental factors and purely chemical reactions.

3. Your answer should include the following points:

   - Delay or prevention of microbial decomposition of food.
   - Delay or prevention of self decomposition of food.
   - Prevention of damage to food caused by insects, rodents, birds and mechanical causes.

4. Your answer should include the following points:

   - Microbiological spoilage
   - Spoilage by physical causes

5. Your answer should include the following points:

   Dried fruits can have a number of microorganisms but due to decreased water activity, heat treatment during dehydration and fumigation, the microorganisms may be killed so unable to cause spoilage, but, spores of bacteria and molds may survive and cause spoilage.

6. Your answer should include the following points:

   Acetification: It is the process of conversion of ethanolic liquid into acetic acid by the activity of acetic acid bacteria.

   Putrefaction: The anaerobic decomposition of the protein, peptide or amino acid results in the production of obnoxious odour which is called as putrefaction.

   Fermentation: It is the process in which the organic compounds are converted into other organic compounds with generation of energy.

   Rancidity: It implies the oxidation of fatty substances giving specific off-odour.

7. Your answer should include the following points:

   In hard swells, both the ends of can remain bulged and rigid. In case of soft swell, the ends are not so hard. On applying some pressure, the ends may go inward (normal) but do not remain normal on the removal of pressure.

8. Your answer should include the following points:

   Water activity (aw): Moisture content is usually expressed in terms of water activity.

9. Your answer should include the following points:

   Jams and jellies have usually low water activity (0.75-0.86) so have lower risk of spoilage. However, if package is opened chances of recontamination could be expected or if there is leakage the product could be spoiled by osmophilic yeasts such as *Zygosaccharomyces Torulopsis*, *Xeromyces*.

10. Your answer should include the following points:

   Fungi

   Mucor,
   Rhizopus,
   Penicillium,
   Aspergillus,
   Alternaria, Cladosporium,
   Byssochlamys

Bacteria

Clostridium butyricum
B. coagulans (flat sour)
E. coli
Lactobacillus,
Leuconostoc mesenteroides
Streptococcus viscosum

Yeast

Saccharomyces

11. Your answer should include the following points:

    Carbonated beverages are usually not spoiled because of inhibitory effect of CO_2 on microorganisms. The acidity (resulting from carbonation and addition of acids) also inhibits microorganisms. Since molds require air, they do not grow on the carbonated beverages but may develop at the surface of uncarbonated soft drinks which contain air above the liquid surface.

12. Your answer should include the following points:

    Following are some of the factors responsible for spoilage: Number and kind of microorganisms, Suitability of temperature, Suitability of food, pH of food and Presence of air

13. Your answer should include the following points:

    Perishable foods: are the foods which spoil readily unless special preservation methods are used (meat, fish, most of fruits and vegetables, egg, poultry milk).

    Semi-perishable foods: Semi-perishable foods like waxed potatoes and some varieties of apple, if handled and stored properly, shall remain unspoiled for a fairly long period.

    Non-perishable foods: are the foods that do not get spoiled until and unless they are handled carelessly such as cereals, sugar.

14. Your answer should include the following points:

    Psychrophiles: These have affinity for low temperatures (8-10^{o}C).

    Mesophiles: These microorganisms grow best at medium temperatures (25-40^{o}C).

    Thermophiles: These microorganisms appear at higher temperatures (50-55^{o}C).

15. Your answer should include the following points:

    Bacillus coagulans

16. Your answer should include the following points:

    The initial number of microorganisms present on the food has a direct relationship with its spoilage. More the number of microorganisms present, rapid is the spoilage.

17. Your answer should include the following points:

    1) Keep the initial microbial contamination as low as possible and create conditions to check the growth of microorganisms.

    2) All efforts be made to apply the preservative technique.

    3) Mechanical disruption of the processed product tissue should not occur.

    4) Inhibit microbial growth by storing the food at low temperature or in inert atmosphere packaging of dried fruits and vegetable products.

    5) Equipments used for handling should be clean and free from contamination.

4.12 SOME USEFUL BOOKS

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4. Lal, G., Siddappa, G.S. and Tandon, G.L. (1986) Spoilage in canned foods. In: Preservation of fruits and vegetables. ICAR Publ., New Delhi, p. 82.

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UNIT 5 CONCEPT, DETERMINATION OF PROCESS LETHALITY REQUIREMENTS AND IMPORTANCE

Structure

5.0 OBJECTIVES

After studying this unit, you should be able to understand:

- kind of foods based on their acidic reaction;
- relationship between pH of foods and heat resistance of microorganisms;
- difference in heat resistance of vegetative cells and spores of microorganisms;
- what is thermal death time and how it is determined?;
- how microorganisms behave under freezing and refrigeration conditions?; and
- the basic principle involved in various methods for controlling microorganisms.

5.1 INTRODUCTION

The foods, which we eat or drink are also excellent substrates (food) for microorganisms, which are present in air, water, soil, utensils and even in raw foods. Under suitable conditions of growth, particularly temperature and moisture, the microorganisms multiply using these food items and produce luxuriant growth. Many foods serve as carrier of various pathogenic and non-pathogenic microorganisms, which may spoil the food by their growth, change of chemical nature of food, release of unpleasant odour, production of various harmful enzymes and toxins. Such foods are unfit for human consumption. For these reasons, it is essential to prevent the entry and growth of microorganisms in our food if present, by suitable processing. Before using a suitable process, we should understand various factors which may influence the effectiveness of a process.

5.2 CLASSIFICATION OF FOODS ACCORDING TO pH

Most foods are derived either from plants or from animals. In this course, we are concerned with foods of plant origin and are known as vegetables or fruits based on their use. These foods have different pH and are classified as low acid foods, medium acid foods, acid foods and high acid foods.

a) Low acid foods

The foods having pH above 5.3 are called low acid foods. For example: peas, corn, lima beans etc.

b) Medium acid foods

The foods which have pH between 4.3 and 5.3 are called medium acid foods. For example: asparagus, beets, pumpkin, spinach etc.

c) Acid foods

Foods which have pH between 3.7 and 4.5 are called acid foods. For example: pears, pineapple, tomatoes etc.

d) High acid foods

Foods having pH 3.7 or lower are included in this category. For example: Berries and sauerkraut.

You must have noted that in general vegetables are low or medium acid foods while fruits are acid or high acid foods.

Most foods are subjected to heat treatment or cooked before use. The heat process is essential in the canning of foods to eradicate the microorganisms, which may be present in the raw food or may enter from the environment during processing; and may spoil the food if not eradicated.

The effect of pH of the food is complicated as the heating at high temperature causes decrease in the pH of low or medium acid foods. Higher the original pH, the greater the drop of pH by heating. Foods artificially adjusted to more alkaline pH give increasing protection to spores against heat as pH increases towards 9.

5.3 RELATIONSHIP BETWEEN pH OF FOOD AND HEAT RESISTANCE OF MICROORGANISMS

The pH of the foods influence the heat resistance of microorganisms. In general cells or spores are most heat resistance in a substrate that is at near neutrality. An increase in acidity or alkalinity hastens killing by heat. However, a change towards acidic pH is more effective than a corresponding change in alkalinity. This will be more clear from the Table 5.1, which shows the effect of pH on heat resistance of spores of *Bacillus subtilis.* Therefore low acid foods are heated under pressure (i.e. temperature above 100^{o}C) while the high acid foods are heated up to 100^{o}C for making free from microorganisms.

Table 5.1: Effect of pH on heat resistance of spores of *Bacillus subtilis* in 1:15 M phosphate buffer (100^{0}C)

pH	Time of survival (min)
4.4	2
5.6	7
6.8	11
7.6	11
8.4	7

5.4 HEAT RESISTANCE OF MICROORGANISMS AND SPORES

The heat resistance of microorganisms varies widely within the species and their forms:

- Thermophiles are more resistance than mesophiles and psychrophiles are least resistance.
- Spores formers are more resistant than non-spore formers. Cocci are usually more resistant than rods.
- The bacteria that clump considerably or form capasules are more resistant to heat than those which do not.
- Cells high in lipid content are difficult to kill than cells having low lipid.

However, there are many notable exceptions to the above mentioned general statements.

Higher the optimal temperatures for growth, the greater the resistance to heat. Thermal death time of bacterial cells of a few microorganisms are exemplified in Table 5.2.

Table 5.2: Thermal death time of bacterial cells

Bacteria	Time (min)	Temperature (^{o}C)
Gonococcus	2 – 3	50
Salmonella typhosa	4.3	60
Staphylococcus aureus	18.8	60
Escherichia coli	20-30	57.3
Streptococcus thermophilus	15	70-75
Lactobacillus bulgaricus	30	71

The heat resistance of microbial spores is much higher than the vegetative cells, and vary with the species of microorganism and conditions during sporulation. Resistance may vary from <1 min to 20 h at 100^{o}C. Similar to non-spore forming species, the spore forming species which have higher optimal temperature for growth are more resistant to heat than those spore forming species having lower optimal growth temperatures.

Simultaneous growth of two spores formers enhances the resistance of spores having lower heat resistance, e.g. *Clostridium perferingens* growing with *C. sporogenes*. Thermal death times of spores of a few microbial species are given in Table 5.3.

Table 5.3: Thermal death times of bacterial species

Species	Thermal death at 100^{o}C (min)
Bacillus anthracis	1.7
Bacillus subtilis	15-20
Clostridium botulinum	100-300
Clostridium calidotolerans	520
Bacillus coagulans (flat sour bacteria)	> 1030

Above examples of thermal death times of vegetative cells as well as of spores are at various concentrations of cells or spores in different substrates. These values may change to lower or higher under different conditions.

What happens to enzymes in food by heat treatments?

Most foods and microbial enzymes are destroyed at 79.4^{o}C, however some may withstand higher temperatures, especially if high temperature for short duration is employed. This is called **pasteurization**, which you will learn later in this course.

5.5 THERMAL DEATH POINT (TDP)

Thermal death point is the lowest temperature at which all microorganism in a liquid suspension are killed in 10 minutes.

5.6 THERMAL DEATH TIME (TDT OR t_D)

The thermal death time is defined as the time required, at a given temperature, for heat killing of a population of a single species of microorganism in aqueous suspension. t_D depends on the size of the population and on the pH of the suspension. It is an important factor for controlling the microorganisms by heat treatment or to determine the heat resistance of a microorganism.

5.7 DETERMINATION OF THERMAL DEATH TIME (t_D)

The description of all the procedure and equipments/apparatus, used in the determination of thermal death time is beyond the scope of this course. However, a simple glass-tube method, used in canning industry is discussed here.

5.7.1 Glass Tube Methods

A known population of cells of an axenic culture in a small volume (1 ml) of buffer solution is sealed in small glass tube. The tubes are heated in a thermostatically controlled bath to a selected temperature. The tubes are selected periodically, cooled immediately to 0^oC and the population of viable cells is determined. In case of spores, the suspension is first pasteurized to kill the vegetative cells, if present, before subjecting the spore suspension to d_T test. This is necessary as the lysed vegetative cells may have protective effect on spore-population.

Care is also taken to break up the clumps and remove the growth medium by centrifuging and washing. The volume of microbial suspension added to the buffer is kept 1-2 percent to avoid the change in the composition of heating substrate and the vials containing the suspension are brought to constant temperature, usually 0^oC before subjecting to heat treatment. If temperature above 100^oC is selected, oil bath instead of water bath is used. The test is always made in multiple tubes. Viability of the surviving organism after heat treatment should be checked on appropriate medium containing all the nutrients, which support maximum growth of that organism.

5.7.2 Decimal Reduction Time

When a microbial population is heated, the cells die at a constant rate. For example, suppose a population of 1 million (10^6) cells has been heated to a high temperature for 1 minute and 90% has died. We are now left with 100,000 (10^5) cells. If the leftover population is heated for another 1 minute, 90% of the population leaving 10000 (10^4) survivers. Thus the each one minute of heat treatment will reduce 90% of the remaining population. This is shown in Table 5.4 and is known as decimal reduction time (DRT) and represented by *D*. It can be defined as the time of heating at a temperature to cause 90% reduction in the population of viable cells or spores.

Table 5.4: Microbial death rate at constant temperature

Time (min)	Death min^{-1}	Number of survivors
0	0	1,000,000
1	900,000	100,000
2	90,000	10,000
3	9,000	1,000
4	900	100
5	90	10
6	9	1

The D value (Decimal reduction time) may also be defined as the 'time at given temperature for the surviving population' to be reduced by 1 log cycl. Please refer Figure 5.1, if we extrapolate the times from 10^3 and 10^2, the time difference is (3.5 – 2.5 = 1min is D). It means within 1 min initial population will decrease by 90 per cent (from 1000 to 100, Difference 1000 – 100 = 900).

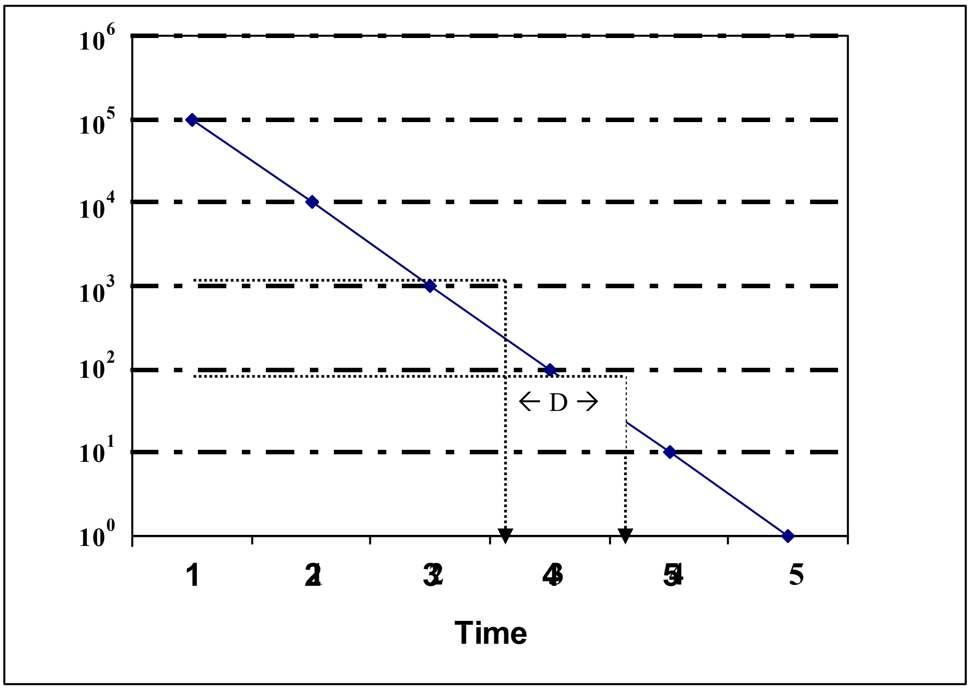

Figure 5.1: A microbial death curve showing constant death rate of cells i.e. 90% per minute D value may be calculated from the curve by extrapolating lines from the Y axis and calculating the time difference.

5.7.3 Thermal Death Time Curve (TDT Curve)/Kinetics

The methods to construct TDT curve are: (i) The growth – no growth method (ii) classical end point method and (iii) based on *D* values. We shall here discuss the method based on *D*-values. D values can be calculated at different temperatures (refer 5.7.2). As the temperature is increased, the D value decreases. It means if we heat the sample at high temperature, it will take less time to kill the microorganism in a given food sample. If we plot log D values against temperature, we will get a straight line. From this we can derive another important parameter in heat processing Z, the temperature change which results in a ten fold (1 log) change in D.

$$Z = (T2 - T1)$$

D value for a known population of cells or spores of a microbial species at several temperatures can be estimated. By plotting D values on the logarithmic scale against temperature TDT curves can be constructed (Figure 5.2).

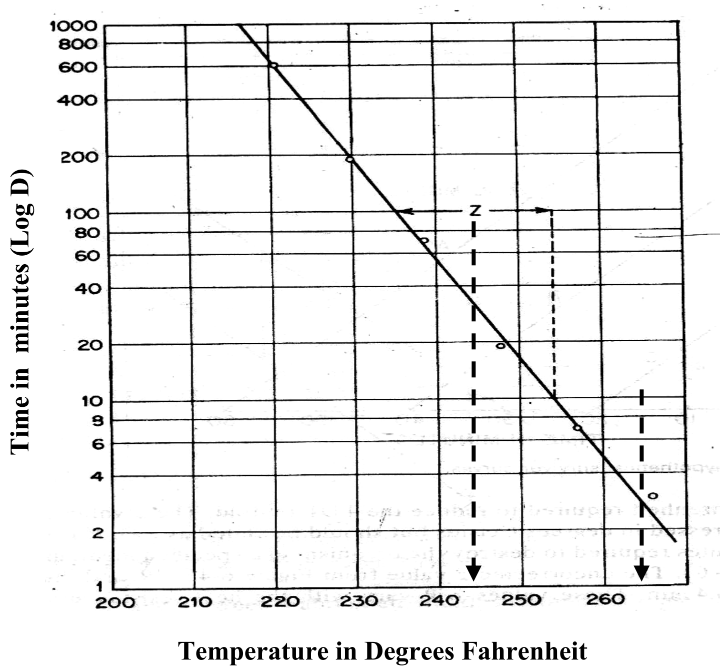

Figure 5.2: TDT curve for spores of flat sour bacteria; 115,000 spores per ml in corn at pH 6.1 (z = 19).

If we are interested to process the food item so that it may be free from any spore or microorganisms, first we have to calculate D, Z and F values. *F* is the time in minutes required to destroy the organism in a specified medium at 121°C. These values vary with the heat resistance and concentration of the test organisms and with the medium in which it is heated. From the *Z* and *F* values process times can be calculated.

5.7.4 12D Concept

Canned foods are susceptible to the spores of the organism *Clostridium botulinum*, this organism causes botulism. As a safety measure, the canning industry use the 12*D* heat treatment for low acid foods. In this process enough heat is provided to reduce 10^{12} spores of *C. botulinum* to 1 spores per ml. It can be explained as follows.

Assuming that *D* has a value of 0.21 minutes for spores of *C. botulinum* at 121°C and that out of 12 cans of food contains 1 spore. A heat process at 121°C for 2.52 min would reduce the spores to 1 spore in 10^{12} cans. The value of 2.52 min has been arrived by the following formula:

$$F_o = D_{121} (\log a - \log b)$$
$$= 0.21 (\log 1 - \log 10^{-12})$$
$$= 0.21 \times 12$$
$$= 2.52$$

5.8 DETERMINATION OF PROCESS LETHALITY REQUIREMENTS AT LOW AND HIGH TEMPERATURE

5.8.1 Heat Penetration

In heat/thermal processing of foods, the ratio of penetration of heat into a food is very important, because every part of food in a container must get adequate heat to prevent spoilage. The part which heats most slowly is the critical one; and this is near the centre of container. Solids are heated by conduction while liquids by convection. Foods which are semisolid are heated by combination of both conduction as well as convection. Conduction is slow in foods and rapid in metals.

The factor that determine the time required to bring the centre of the container of food upto the sterilizing temperature are as follows:

i) Material of which the container is made

Glass has slower rate of penetration than metal (tin can).

ii) Size and shape of container

Large container takes long time than small container. Less the radius of container faster the heating. For example: long slim cylinder will heat faster than compact wide cylinder of the same volume.

iii) Initial temperature of food

For the foods with the higher initial temperature the average temperature during heating is higher than in foods having lower initial temperature. A high initial temperature is important in processing canned foods that heat slowly. For example: pumpkin, cream style corn etc.

iv) Initial temperature of retort (steam sterilizer)

Fastest heating takes place in initially hot retort than retort having initially low temperature. Therefore, preheated retort should be used.

v) Consistency of food, size and shape

Consistency of food, size of food pieces and even their shapes affect the penetration of heat. The changes that takes place during heating (cooking effect) also affect the heat penetration. Penetration of heat in large pieces takes more time than in small pieces. This is applicable in foods, which retain their shape and even size during heating. For example: peas, plum, beats, whole grain corn etc.

Some foods become mushy or viscous during heating. In such foods penetration is slow. For example: Sweet potatoes, pumpkin, etc.

Pieces that layer like asparagus layers or spinach layers interfere with convection current

Sauces added on baked beans slow down heat penetration more than plain sauce. Starch interferes increasingly as the concentration is raised. Sodium chloride is never added in high concentration as it slows down rate of heating. Rate of heat penetration also decreases with increasing concentration of sugars; however this effect is counteracted some what by the marked decrease in the viscosity of sugar solutions. *(Addition of sugar and salt slow down the rate of heating)*

vi) Rotation and agitation

The rotation and agitation of the container of food during heat processing hasten heat penetration, if food is in form of fluid. However, in some food such operation may cause undesirable physical changes.

5.8.2 Cooling of Food after Heat Processing

The cooling operation involves the same principles of heat transfer as the heating process. Rapid artificial cooling is recommended as slow cooling may cause overcooking of the food and may allow the growth of thermophiles.

5.8.3 Determination of Thermal Processes

To determine the thermal processes data on the following two aspects are required:

i) TDT curve for most heat-resistant organism likely to be present in food. For example in low acid foods spores of *Bacillus coagulanse* (flat sour organism), which is a thermophile, may be present.

ii) Heat penetration and cooling curves for the food when packed in specific type of container of fixed size.

There are three methods to determine thermal processes:

- Graphical methods
- Formula method
- Nomogram method

The principle is similar for all the three methods; however the graphical method is most simple and therefore explained here:

Graphical method to determine thermal processes

1. The TDT curve for the most heat resistance organism likely to be encountered is determined in food being canned.

   TDTs from this curve are converted to **lethal rates** for the various heating temperatures. The lethal rate for a temperature is the reciprocal of the TDT. If TDT is 400 min at 126.7^{o}C to kill the spores in a food, the lethal rate would be 1/400 i.e. 0.0025.

2. Heat penetration and cooling curve for the food and can size involved are determined.

3. The lethal rates for different temperatures at the centre of can during the length of heating and cooling process are plotted on the heat penetration or cooling curves (see Fig. 5.3). In this figure the lethal rates are 0.01 units and times are 10 minutes for a square. An area equivalent to 10 squares under the lethality curve is unity. This means that the destruction of all the spores or cells has been accomplished. If this area is less than unity (i.e. less than 10 squares), the process is inadequate, and if more than 10 squares, it is greater than needed. The area beneath the curve is

measured by planimeter. In Figure 5.3 the heat treatment of 56 min at 126.7°C and 78 min at 121°C are adequate.

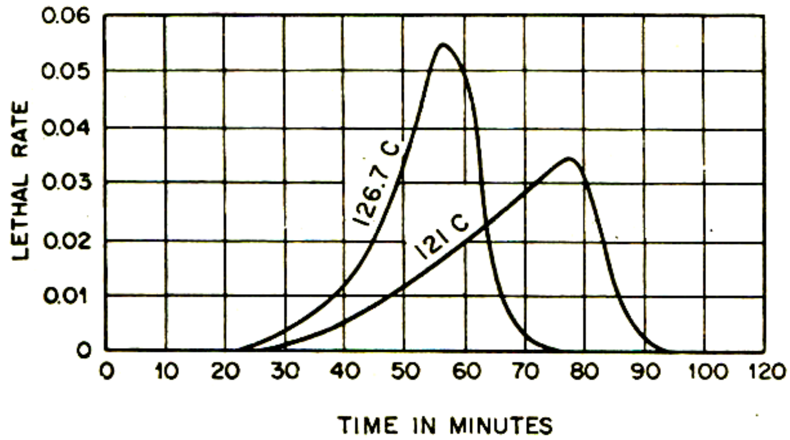

Figure 5.3: Equivalent lethality curves with retort at 126.7°C. (50,000 spores per ml)

5.9 BEHAVIOUR OF MICROORGANISMS UNDER FREEZING AND REFRIGERATION ENVIRONMENTS

Low temperatures are used to retard chemical reactions, and actions of food enzymes and to reduce slow down or stop growth and activity of microorganisms in food. The lower the temperature, the slower will be the chemical reactions, enzyme and microbial growth; and temperature below certain level will prevent the growth of a microorganism. Each microorganism has a specific **Cardinal temperature** i.e. the minimal temperature and maximal temperature at which it can grow and optimal temperature at which the growth is fastest in the shortest time. As the temperature drops below the optimal temperature towards the minimal, the rate of growth of organism decreases and is slowest at the minimal temperature. Below minimal temperature, the growth will stop but slow metabolic activity may continue. Therefore cooling down of a food from normal temperature has different effects on various microorganisms and slow down the growth of others; however the extent would vary with different species and even strains of microorganisms. A further decrease of 10°C would stop growth of more organisms, and make still slower the growth of the others. Therefore storage at low temperature influence the type of spoilage microorganisms which may predominate as illustrated in Table 5.5.

Table 5.5: Growth rate of Pseudomonas fragii at various temperatures

Temperature (°C)	Exponential growth rate (generation h^{-1})
0.0	0.09
2.5	0.13
5.0	0.20
7.5	0.29
10.0	0.38
20.0	0.92

5.9.1 Growth of Microorganisms at Low Temperature

In general, freezing prevent the growth of most food born microorganisms and refrigeration slow down growth rates except for *Clostridium botulinum* type E. Temperature below 5-6°C or less, effectively retard the growth of most food spoilage microorganisms. However, some of the microorganisms may survive at subfreezing temperature in frozen food. (Table 5.6 and 5.7)

Table 5.6: Microorganisms able to grow at subfreezing temperatures

Organisms	Temperature (°C)
Molds	
Claedosporium	–6.7
Sporotrichum	–6.7
Penicellium	–4.0
Monilia	–4.0
Yeast	
Yeast (one strain)	–34.0
Yeast (two strains)	–18.0
Bacteria	–5.0 to –17.8

Table 5.7: Different microorganisms able to grow in different frozen foods

Organisms	Food	Temperature (°C)
Bacteria	Meat	– 5.0
	Cured meats	–10.0
	Fish	–11.0
	Vegetables	–12.2
	Ice cream	–10.0
Yeast	Meat	– 5.0
	Oysters	–17.8
Molds	Meat	– 7.8
	Vegetables	– 7.8
	Barries	– 6.7

5.9.2 Effect of Freezing and Subfreezing Temperature on Microorganisms

Feezing usually results in a considerable reduction in the number of viable organisms in a food. The reduction in recoverable numbers can be the result of lethal or sublethal effects.

a) Lethal effects

Though several cells of microorganisms are killed by freezing, a few may remain viable with little or suspended metabolic activity. The lethal effects are due to denaturation or flocculation of essential cell proteins or enzymes possibly as a result of the increased concentration of solutes in the unfrozen water or perhaps in part because of physical damage by ice crystal. Rapid cooling of cells from an optimal temperature to 0^oC is most injurious and may lead to cell death due to cold shock. It is probably due to crystallization of the liquids in the membrane which damage to the permeability of the cell or due to the release of repair enzyme inhibitors, e.g. **ribonuclease inhibitors.**

b) Sublethal effects

Freezing of food may cause cryo injury to the microorganisms present on food. Such injured cells are referred as freeze injured, frost injured, cryo-injured or metabolically injured. Such cells are not really dead and may recover to start refunctioning, if repair time is permitted or additional nutritional factors are added to the enumeration media. This fact of cryoinjury is of great significance in the microbiological examination of foods.

5.9.3 Factor Affecting Microorganisms during Freezing

1. The resistance or sensitivity of microorganisms vary with the kinds of microorganisms, their form and growth phase. For example:
   a) Thermophiles are most sensitive and psychrophiles most resistance.
   b) Spore formers are more resistance than non-spore formers.
   c) Bacteria in logarithmic phase are more sensitive than in stationary phase.
   d) Rods are more sensitive than cocci.
2. Microorganisms are classified on the basis of sensitivity to freezing:
   i) **Susceptible:** Gram negative bacteria and vegetative cells of yeast and molds.
   ii) **Moderately resistant:** Gram positive streptococci and enterococci.
   iii) **Insensitive:** Spore formers.
3. Freezing parameters:
   i) ***Freezing rate***

      Rapid cooling upto 0^oC is injurious to microbial cells.

   ii) ***Freezing temperature***

      Freezing temperature between -4 to -10 is more injurious than -15 to -30^oC.

   iii) ***Times of frozen storage***

      Maximum death of microorganisms occur during the freezing process. Once the temperature is stabilized, the death is less and very low.

   iv) ***Kinds of food***

      The composition of food influence the rate of killing of microorganisms during freezing and storage. Sugar, salt, protein, colloids, fats and other substance in foods provide protection to the microorganisms while low pH and high moisture hasten the death.

v) ***Slow defrosting of food cause death*** of microorganisms.

vi) ***Freezing and thawing***

Maximum casualty of microorganisms occur if foods are repeatedly frozen and thawed.

5.9.4 Effect of Freezing on Constituents of Microbial Cells

With the lowering of temperature, water in cell gets frozen. As a result the unfrozen fluids in cell gets concentrated with solutes (salts, proteins, nucleic acids, etc). This may change the pH of cellular matter, concentrate electrolytes, alter colloidal states, denature proteins and increase viscosity. Ice crystals also form outside the cell due to the freezing of water molecules in food. These extracellular ice crystals draw water from the cell causing dehydration or concentration effect. Intracellular ice crystals due to the freezing of water may rupture cell membrane and alter the permeability of cell membrane. Intracellular ice crystals are more injurious than the extracellular ice crystals to the microbial cells.

5.10 CONTROL OF MICROORGANISMS BY VARIOUS MEANS

Most foods are either of plants or animal origin. Their spoilage is prevented by controlling microbial growth on them by using various methods. Some important methods are listed below:

1. Asepsis or preventing contacts with microorganisms.
2. Killing the microorganisms by heat treatment.
3. Keeping away from the microorganism e.g. maintenance of anaerobic conditions in sealed or evacuated container.
4. Storage at low or ultra low temperature
5. Drying.
6. Increasing osmotic concentration in foods.
7. Mixing with preservative.
8. Change of pH
9. Mechanical destruction in industry: grinding or high pressure.

Usually a combination of more than one method is used to control the microbial spoilage of food. For example: canned foods are preserved by heat treatment followed by evacuation and sealing of can. Similarly, many processed foods involve heating, mixing with preservative, evacuation of air and sealing.

5.11 PRINCIPLES INVOLVED IN VARIOUS METHODS TO CONTROL MICROBIAL SPOILAGE OF FOOD

The basic principle involved in various methods to control microbial spoilage of foods are prevention or delay of microbial decomposition. These are achieved by followings methods:

a) By keeping out microorganisms. For example: Aseptic condition during processing of food.

b) By the removal of microorganisms: For example

- By removing the microbially infected portion of food, covering, skin etc.
- Washing of raw food.
- Filteration.

c) By hindering the growth and activity of microorganisms by low temperature, drying, anaerobic condition or chemical.

d) By killing the microorganisms: sterilization by heat or radiation.

5.12 LET US SUM UP

Human foods are excellent substrate for various microorganisms, which are present in air, water, soil, raw foods, on the body of living and non-living organisms. These microorganisms may harm the body if enter in the body/tissue due to rupture or injury of outer covering layer. Many of these microorganisms may enter the food during the processing and remain either dormant for long time till get the right conditions for multiplication, if consumed, cause unpleasant odour or taste making the food unfit for consumption. Such spoilage is called microbial spoilage of food.

Prevention of microbial spoilage of foods depend upon the kind of foods. The acidity or pH of the food influence heat resistance of microorganisms. Microbial cells are more resistance to heat at pH near to neutrality and therefore, low acid foods are heated under pressure to kill the microorganisms, where as the high acid foods are heated upto 100^{o}C for short duration to make free from organisms.

The thermal death time (TDT) which is defined as the time required to kill a known population of microorganisms at a certain temperature by heat. This value differ for different microorganisms and also on various environmental factors. TDT values are of great significance in heat control of microorganisms.

The death of microbial cells is at constant rate and is expressed in *D*-value i.e. decimal reduction time. *D*-values of a microbial species at several temperatures are estimated and plotted against temperature to construct curve, which are used to determine the actual time required for killing microbes in a food at a particular temperature. In practice 12*D* concept is used in canning industry. This is based on the reduction of 10^{12} spores ml^{-1} of *Clostridium botulinum* in low acid food to 1 spore ml^{-1} by heat treatment.

Low temperature under freezing and refrigeration reduce microbial growth and at 0^{o}C most of the microorganisms stop the growth. However a few exceptions of molds, yeast and bacteria, which may grow up to –6 to –38^{o}C have been encountered.

Freezing may have lethal or sub-lethal effect on microbial cell. In sub-lethal effect the freezing injury makes the microbial cell unable to multiply, however under favourable conditions, such cells may get repaired and grow.

The various method for controlling microorganisms are asepsis, heat treatment, anaerobic conditions, storage at low temperature, drying, increasing osmotic concentration, mixing with preservatives, change of pH, irradiation and mechanical destruction by grinding or high pressure. The basic principle involving in these methods are; prevention or delay of microbial decomposition by keeping out or removing the microorganisms or creating suboptimal conditions for survival and growth of microorganisms or by killing the microorganisms.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are acid foods?

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2. Based on acidic reaction of food, which foods require more heating time to kill the microorganisms?

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3. Which of the two is more resistant to heat and why? *Escherichia coli* or *Clostridium botulinum.*

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4. Define thermal death time.

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5. Define thermal death point.

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6. What do you understand by decimal reduction time?

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7. Why TDT curves are constructed?

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8. What is 12D concept?

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9. Thermal processing of food is affected by the …………………. of food.

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10. Which method is most common and simple to determine thermal processes?

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11. Will all microorganisms stop growing, if the food is stored at 0°C?

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12. What is cryoinjury?

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13. Should the food be cooled rapidly to 0^{o}C to kill microbial cells?

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14. Intracellular ice cause ....

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15. Microorganisms in food can be controlled by ....

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16. Spores are more resistant to heat than ....

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17. Which of the following microorganisms is insensitive to freezing:

i) Escherichia coli
ii) Vibrio cholerae
iii) Clostridium botulinum

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18. Freezing of food is one of the important method to prevent their spoilage on what principle it is based?

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19. Most microorganisms should be killed but the enzyme should not be destroyed. What method of heat processing should be applied?

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20. If heat treated food is cooled slowly, what kind of microorganisms during storage may grow.

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5.13 KEY WORDS

TDP : Thermal death point is the lowest temperature at which all microorganisms in a liquid suspension are killed in 10 minutes.

TDT : Thermal death time is defined as the time required, at a given temperature, for heat killing of a population of a single species of microorganism in aqueous suspension.

D Value : Decimal reduction time is defined as the time of heating at a temperature to cause 90% reduction in the population of viable cells or spores.

12D Concept : A process in which enough heat is provided to reduce 10^{12} spores of *clostridium botulinum* to 1 spores per ml in canned food.

5.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   Food which have pH between 3.7 and 4.5. Example: pear, pineapple and tomatoes.

2. Your answer should include the following points:

   Low acid foods.

3. Your answer should include the following points:

   Clostridium botulinum as it is spore former.

4. Your answer should include the following points:

   Thermal death time is the minimum time required to kill a population of microorganisms in liquid suspension at certain temperature.

5. Your answer should include the following points:

   Thermal death point is the minimum temperature required to kill population of microorganimsm in liquid in 10 min.

6. Your answer should include the following points:

   By any killing agent, the death of microorganisms is at a constant rate. Suppose a population of 10^6 cells are subjected to heat treatment, 90% of them will die in first minute. Of the remaining population, 90% will die in next one minute and so on until all the population die.

7. Your answer should include the following points:

   TDT curves are constructed to determine the thermal process time at different temperature to kill the microorganisms in a food.

8. Your answer should include the following points:

   It is a concept of time required to reduce 10^{12} spores of *Clostridium botulinum* in 1 ml suspension to 1 spore by heating to certain temperature. It is used in canning industry.

9. Your answer should include the following points:

   Thermal processing is affected by the **consistency** of food.

10. Your answer should include the following points:

    Graphic method.

11. Your answer should include the following points:

    No; psychrophiles will continue growing.

12. Your answer should include the following points:

    Injury to microbial cells during freezing.

13. Your answer should include the following points:

    Yes.

14. Your answer should include the following points:

    Rupture of cell membrane leading to the leakage of cell constituent.

15. Your answer should include the following points:

    Sterilization

16. Your answer should include the following points:

    Vegetative cells

17. Your answer should include the following points:

    Clostridium botulinum

18. Your answer should include the following points:

    Reducing or suspending the metabolic activity and growth.

19. Your answer should include the following points:

    Pasteurization

20. Your answer should include the following points:

    Thermophiles

5.15 SOME USEFUL BOOKS

1. Adams, M.R. and Moss, M.O. (1995) Food Microbiology. Low cost Indian addition published by New Agro International (P) Limited Publishers, New Delhi 398p.

2. Frazier W.C. and Westhofl D.C. (1967) Food Microbiology. Tata McGraw Hill Publishing Co., New Delhi 540p.

3. Jay, J.M. (1970) Modern Food Microbiology. Van Nostrand Reinhold Co., London. 328p.

UNIT 6 THERMAL CONTROL OF MICROORGANISMS

Structure

6.0 OBJECTIVES

After studying this unit, you should be able to:

- make you understand the principals of food preservation using high temperatures;
- explain various processes for thermal preservation;
- describe the terms associated with heat preservation; and
- discuss the causes of spoilage of heat processed products and common spoilage organisms.

6.1 INTRODUCTION

The minute living organisms, not visible to the naked eye and classified as microorganisms, are virtually everywhere. Those of primary medical interest are bacteria, viruses, spirochetes, rickettsia, molds, and yeasts. They flourish in the soil of the farms that grow our grains, fruits and vegetables, on the hides and feathers of our meat animals and on the fins and organs of the seafood we eat. Though there are innumerable genera and species of each class of microorganisms, not all are of medical significance or involved in disease processes. Many of these organisms can be beneficial. In fact the predominance are composed of those that are necessary to food production, friendly environments, and metabolic processes, examples being cheese/wine production, decomposition of organic matter, and digestion of food. Lactic acid bacteria in the dairy industry, yeasts in the baking and brewing industries, molds for specialty cheeses are examples of "domesticated" microorganisms. But in a many cases these microscopic flora create serious problems in our food supply. These problems fit into two categories. **Food spoilage** occurs when the food becomes unpalatable as the result of microbial growth. Products develop undesirable flavors, odors, appearances or textures via microbial action. The other, more dangerous problem is **food poisoning**, which occurs when the organisms present in food cause human illness or death. The microorganisms either produce a toxin or cause an infection, generally intestinal, when consumed. Those organisms that spoil product are typically called **spoilage organisms**, while those that can make people sick are referred to as **pathogens**. Therefore, to avoid both of these problems we need to understand the techniques which prevent their growth.

Food preservation has been around for a long time. The technique of food preservation may vary but the goal of food preservation has been the same **i.e. to keep the food in a stable condition over a period of time so that it will not spoil or make people sick.** There are various ways of food preservation, including chemical preservation, modified atmospheres, irradiation, low temperature preservation, preservation by drying and high temperature preservation.

6.2 THERMAL PRESERVATION OF FOODS

The most common method of killing microorganisms is to subject them to a heat treatment. High temperatures act by killing vegetative cells and also spores and denaturing the food enzymes. It may also act to destroy toxins produced by certain microorganisms.

The heat treatment used depends on the following factors. In order to safely preserve foods using heat treatment, the following must be known:

- What time-temperature combination is required to inactivate the most heat resistant pathogens and spoilage organisms in one particular food? The higher the temperature, the less time needed and vice versa. Heat destruction of microorganisms is a gradual phenomenon the longer is the treatment time at lethal temperatures, the larger is the number of microorganisms killed. As higher is treatment temperature the shorter is the time required to kill microorganisms and lower is heat induced damage to food products.

- What are the heat penetration characteristics in one particular food, including the can or container of choice if it is packaged?

- What are the types of micro-organisms present in the food material? The thermal death time of different microorganisms vary widely with the species. Different foods will support growth of different pathogens and different spoilage organisms so the target will vary depending upon the food to be heated.

- What is the concentration of the microorganisms? The higher the concentration, the more time is needed.

- What is the state of the microorganism? Spores are more resistant than vegetative cells. Organisms that have been stressed are more susceptible to heat.

- What is effect of heat on the product? Obviously, the temperatures required to kill microorganisms affect most food products.

- The degree of heat penetration also must be considered. Preservation processes must provide the heat treatment which will ensure that the remotest particle of food in a batch or within a container will reach a sufficient temperature, for a sufficient time, to inactivate both the most resistant pathogen and the most resistant spoilage organisms if it is to achieve sterility or "commercial sterility", and to inactivate the most heat resistant pathogen if pasteurization for public health purposes is the goal

- What is the effect of various environmental factors, such as pH and salts or solutes. Food acidity / pH value has a tremendous impact on the target in heat preservation/ processing.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between spoilage organisms and pathogens?

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2. What is food preservation?

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3. Write various ways of food preservation?

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4. List important factors which need consideration in order to safely preserve foods using heat treatment?

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6.3 HEAT PRESERVATION PROCESSES

The most common type of food preservation by high temperatures is cooking. However, there are many more processes that involve the use of temperature above that of ambient air.

6.3.1 Sterilisation

By sterilisation we mean complete destruction of micro-organisms. Because of the resistance of certain bacterial spores to heat, this frequently means a treatment of at least 121° C (250° F) of wet heat for 15 minutes or its equivalent. It also means that every particle of the food must receive this heat treatment. If a can of food is to be sterilized, then keeping it at 121° C or retort for the 15 minutes will not be sufficient because of relatively slow rate of heat transfer through the food in the can to the most distant point. In such cases time needs to be increased.

6.3.2 Commercially Sterile Food Products

Sterile means free of life of every kind and is actually achieved under very limited conditions. The control of microorganisms in medicine, industry, sanitation, food, and feed service involves the acceptance that sterilization is most often not achievable without destroying or severely damaging the product. Only Low Acid Foods [LAF], having pH higher than 4.6, must be sterilized, because all microorganisms are able to grow in LAF. More acid products [pH equal/lower than 4.6] do not allow the growth of pathogenic spore forming bacteria. Then Sterilization is not required. Hence **Commercial Sterility** is a term commonly used in the canning industry meaning the condition achieved by the application of heat sufficient to render the processed product free from viable microorganisms (including those of known public health significance), capable of growing in the food under normal non-refrigerated temperatures at which the food is likely to be held during distribution and storage.

The process was developed by Nicolas Appert and published in 1810. All vegetative organisms that could grow in the food and cause spoilage under normal handling and storage conditions are destroyed. However **commercial sterile** foods may contain a small number of heat resistant bacterial spores, but they will not multiply under normal handling and storage conditions. Types of commercially sterile processes include canning, bottling, and aseptic processing. Commercial sterilization must make sure the numbers of surviving spores are at an acceptable level. The acceptable number of spores will depend on what type of damage they are capable of causing if they start to grow.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is sterilization?

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2. What is commercial sterility? How commercial sterilization is different from sterilization?

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6.4 PASTEURIZATION

In the previous section you have read about strerilzation and commercially sterile foods. Now we will discuss milder heat treatment i.e. pasteurization. It is one type of preservation by heat that most people are familiar with. It is process of heating a liquid, particularly milk, to a temperature between 55 and 70 degrees C (131 and 158 degrees F), to destroy harmful bacteria. This process is named after the French chemist **Louis Pasteur**, who devised it in 1865 to inhibit fermentation of wine. Pasteur's aim was to destroy bacteria, molds, spores etc. He discovered that the destruction of bacteria can be performed by exposing them to certain minimum temperature for certain minimum time and the higher the temperature the shorter the exposure time required. Through this process, all of the bacteria (such as *E.coli, Lysteria*, and *Salmonella)* are not destroyed, it still exists in pasteurized products, but in very low concentrates. Refrigeration keeps the bacteria from further growth, very low. There are other bacteria that aren't harmful to humans, but they produce acids that turn the milk sour. They are called lactophilic because they consume the lactose in milk and produce acids. The extent of the pasteurization treatment required is determined by the heat resistance of the most heat-resistant enzyme or microorganism in the food. For example, milk pasteurization is based on *Mycobacterium tuberculosis* and *Coxiella burnetii*. These two organisms are the most heat resistant of pathogens that are not spore forming. Milk is a product that most people know is pasteurized. It is pasteurized by heating at a temperature of 63 degrees C (145 degrees F) for 30 minutes, rapidly cooling it, and then storing it at a temperature below 10 degrees C (50 degrees F).

Pasteurization is a comparatively low order of heat treatment, generally at a temperature below the boiling point of water. The more general objective of pasteurization is to extend product shelf-life from a microbial and enzymatic point of view. Pasteurization is frequently combined with another means of preservation - concentration, chemical, acidification, etc. Blanching is a type of pasteurization usually applied to vegetables mainly to inactivate natural food enzymes. Depending on its severity, blanching will also destroy some microorganisms.

Depending upon time and temperature treatment there are three kinds of pasteurization processes.

6.4.1 Low Temperature Long Time (LTLT)

Where pasteurization time is in the order of minutes and related to the temperature used; two typical temperature/time combinations are as following: 63°C to 65°C for 30 minutes or 75° C over 8 to 10 minutes. Pasteurization temperature and time will vary according to:

- nature of product; initial degree of contamination;
- pasteurized product storage conditions and shelf life required.

In LTLT pasteurization it is possible to define three phases:

- heating to a fixed temperature;
- maintaining this temperature over the established time period (= pasteurization time);
- cooling the pasteurized products: natural (slow) or forced cooling.

This is a typical batch method where a quantity of milk is placed in an open vat and heated to 63°C and held at that temperature for 30 min. Sometimes filled and sealed bottles of milk are heat-treated in shallow vats by that method and subsequently cooled by running water.

6.4.2 High Temperature Short Time (HTST)

HTST pasteurization is characterized by a pasteurization time in the order of seconds and temperatures of about 85° to 90° C or more, depending on holding time. Typical temperature/time combinations are as follows:

- 88° C for 1 minute
- 100° C for 12 seconds
- 121°C for 2 seconds.

While bacterial destruction is very nearly equivalent in low and in high pasteurization processes, the 121°C/2 seconds treatment give the best quality products in respect of flavour and vitamin retention. This is the most widely used process. The “hold time” is typically 125°C to pasteurize milk. This process is a continuous method and a “hold tube” is used. The “hold tube” is the tubing in the system that transports the milk after the point where the product is heated. The tubing is sized so that it takes 15-20 seconds for the product to travel all the way through it. When it reaches the end, if the temperature is at 125°C or hotter, it is considered pasteurized. It is then cooled and put in storage. The warm milk passes through the cooling section where it is cooled to 4° C or below by coolant on the opposite sides of the thin, stainless steel plates. The cold, pasteurized milk passes on to a storage tank filler for packaging.

6.4.3 Ultra High Temperature (UHT) Processing Treatments

In this method, milk is exposed to a brief, intense heating, normally to temperatures in the range 135-140 °C but for a very short time, a second or less. The treatment kills all microorganisms that would otherwise spoil the product. The process depends upon a fairly complicated *sterilizer/aseptic filling* design. The two stages of effective heat sterilization followed by aseptic filling represent an integral system. Frequently the packaging material for UHT milk is cardboard which must be chemically sterilized prior to the filling operation

This method is used mainly for coffee creamers and boxed juices with the exception of Europe. They pasteurize milk in this way. After this is done, there is no need to refrigerate, because it sterilizes the product. Sometimes the products can have a "cooked" taste that can be detected after being brought to such a high temperature.

Industrial applications of pasteurization process are mainly used as a means of preservation for milk and fruits and vegetable juices and specially for tomato juice.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the scientist who invented Pasteurization. In which food material this process is used the most?

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2. Why pasteurization of milk is important?

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3. What are the factors responsible for microbial inactivation during pasteurization?

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4. Does pasteurization kill all the bacteria in the product?

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5. Name the organisms on which milk pasteurization time and temperature is based?

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6. Why HTST pasteurization is better treatment than LTLT?

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6.5 PRESERVATION BY MOIST HEAT

Moisture levels of the food material are a definite influencing factor in the shelf life of food. Moist heat readily kills viruses, bacteria, and fungi by denaturing enzymes whereas dry heat kills by oxidation of cell contents. There is a correlation between the percent of water and the effectiveness of heat to kill microorganisms. Moist heat is a more effective sterilizing agent than dry heat because the moisture increases the rate of heat penetration. Moist heat requires less heat (temperature or time) than dry heat (121°Cfor 10 min of moist heat is equivalent to about 30 min at 200°C dry heat).

For this reason a lot of sterilization procedures use super heated steam that provides moist heat. Temperature over 100^0C requires heating under elevated pressure, (like in a pressure cooker) 121^0C require 100 kpa extra pressure. It is important that no air pockets are allowed to develop when a product being sterilized with steam. In air pockets food is exposed to dry heat and thus the time /temperature is not enough. Moist heat denatures proteins which destroys essential enzyme activities.

Endospores are much more resistant to heat than are vegetative cells. For this reason, moist heat sterilization is aimed at ensuring that endo spores are killed.

Terms Associated with Heat Preservation

Scientists use different terms to refer the effect of moist heat on the preservation of food. These terms include thermal death time, D-value, and z-value.

6.5.1 Thermal Death Time (TDT)

Thermal death time is the amount of time that is necessary to kill a specific number of microbes at a specific temperature. This value is obtained by keeping temperature constant and measuring the time necessary to kill the amount of cells specified.

6.5.2 D-Value

The term D-value refers to decimal reduction time. This is the amount of time that it takes at a certain temperature to kill 90% of the organisms being studied. Thus after an organism is reduced by 1 D, only 10% of the original organisms remain. The population number has been reduced by one decimal place in the counting scheme. When referring to D-values it is proper to give the temperature as a subscript to the D. For example, a hypothetical organism is reduced by 90% after exposure to temperatures of 149°C for 2 minutes, Thus the D-value would be written as D_{300F} = 2 minutes. Several parameters help us to do thermal calculations and define the rate of thermal lethality. The D-value is a measure of the heat resistance of a microorganism. It is the time in minutes at a given temperature required to destroy 1 log cycle (90%) of the target microorganism. (Of course, in an actual process, all others that are less heat tolerant are destroyed to a greater extent). For example, a D-value at 72°C of 1 minute means that for each minute of processing at 72°C the bacteria population of the target microorganism will be reduced by 90%. D-values vary according to the temperature, species of microorganisms, number of initial population, and other factors that may affect thermal resistance. In the illustration below, the D-value is 14 minutes (40-26=14 min.) and would be representative of a process at 72°C.

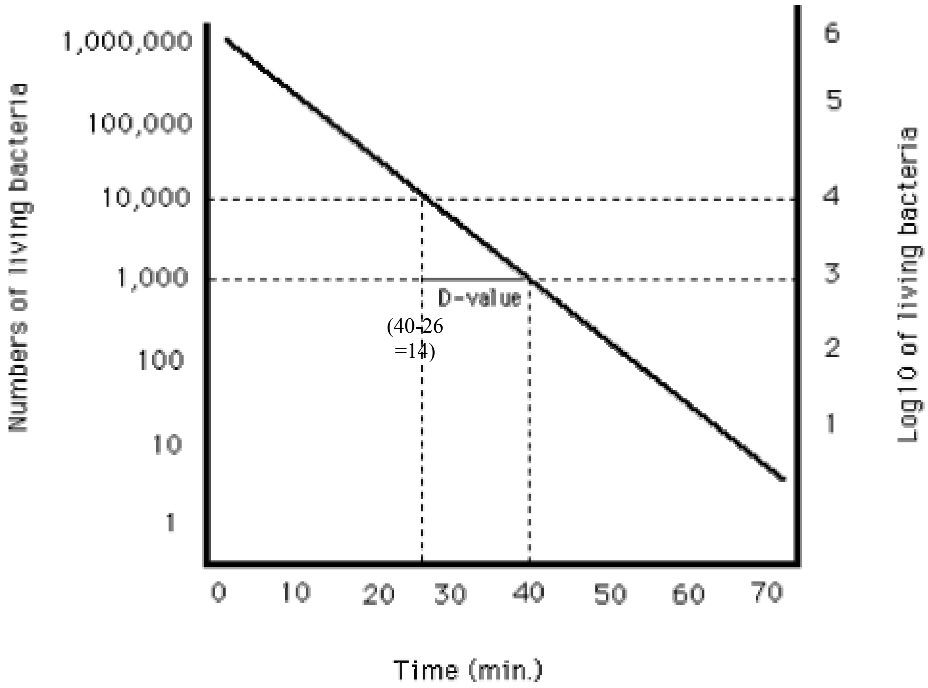

Figure 6.1: The D-value

6.5.3 Z-Value

The Z-value reflects the temperature dependence of the reaction. It is defined as the temperature change required to change the D-value by a factor of 10. While the D-value gives us the time needed at a certain temperature to kill an organism, the Z-value relates the resistance of an organism to differing temperatures. In the illustration below the Z-value is 10°C.

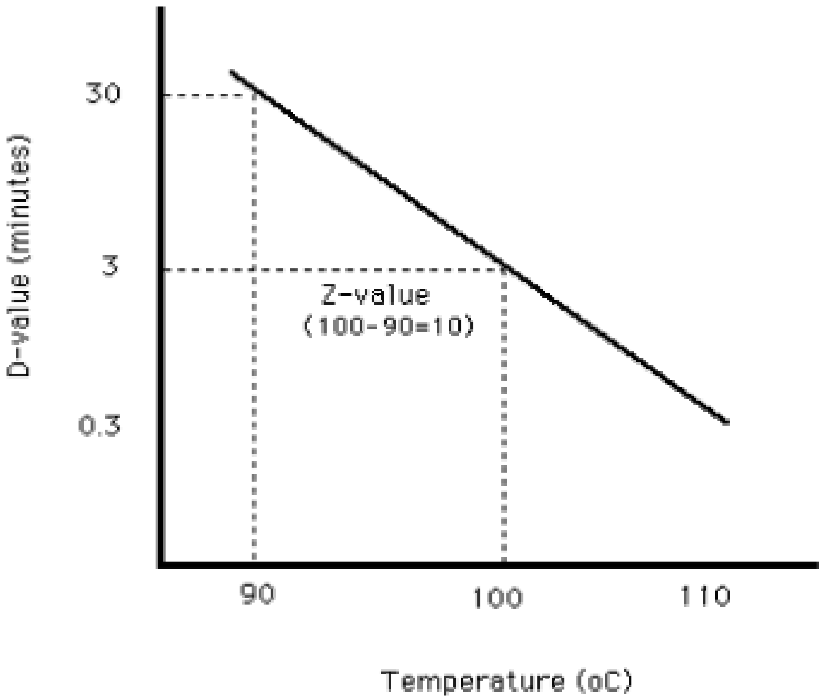

Figure 6.2: The Z-value

The Z-value allows us to calculate a thermal process of equivalency, if we have one D-value and the Z-value. So, if it takes an increase of –12°C to move the curve one log, then our Z-value is 10. So then, if we have a D-value of

4.5 minutes at 66°C, we can calculate D-values for 71°C by reducing the time by 1 log. So, our new D-value for 71°C is 0.45 minutes. This means that each -12°C increase in temperature will reduce our D-value by 1 log. Conversely, a -12°^{0}C decrease in temperature will increase our D-value by 1 log. So, the D-value for a temperature of 60°^{0}C would be 45 minutes.

Reactions that have small Z-values are highly temperature dependent, whereas those with large Z-values require larger changes in temperature to reduce the time. A Z-value of 10°C is typical for a spore forming bacterium. Heat induced chemical changes have much larger Z-values that microorganisms, as shown below:

	Z (°C)	**D121(min)**
bacteria	5-10	1-5
enzyme	30-40	1-5
vitamins	20-25	150-200
pigment	40-70	15-50

Figure 6.3 illustrates the relative changes in time temperature profiles for the destruction of microorganisms. Above and to the right of each line the microorganisms or quality factors would be destroyed, whereas below and to the left of each line, the microorganisms or quality factors would not be destroyed. Due to the differences in Z values, it is apparent that at higher temperatures for shorter times, a region exists (shaded area) where pathogens can be destroyed while vitamins can be maintained. The same holds true for other quality factors such as colour and flavour components. Thus in milk processing the higher temperature, shorter time (HTST) process (72°C/16 sec) is favoured compared to a lower temperature longer time (batch or vat) process since it results in a slightly lower loss of vitamins and better sensory quality.

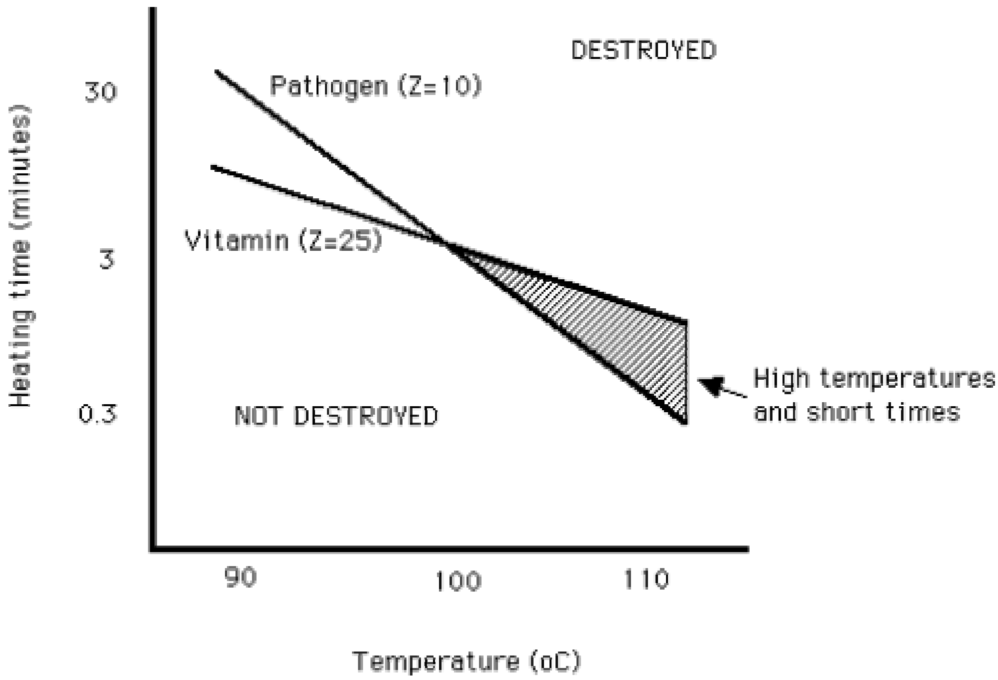

Figure 6.3: The relative changes in time temperature profile

Alkaline phosphatase is a naturally-occurring enzyme in raw milk which has a similar Z value to heat-resistant pathogens. Since the direct estimation of pathogen numbers by microbial methods is expensive and time consuming, a simple test for phosphatase activity is routinely used. If activity is found, it is assumed that either the heat treatment was inadequate or that unpasteurized milk has contaminated the pasteurized product.

6.5.4 12-D Concept

Canned foods are susceptible to the spores of the organism *Clostridium botulinum*. This is the organism that causes botulism. Their bacterial spores can survive many heat treatment processes. However, in modern food production, canned foods are subjected to a time/temperature process that will reduce the probability of the survival by the most heat-resistant *C. botulinum* spores by 12 logs or 12-D at 250F (the temperature used in the calculation of most commercial 12-D processes is 250F, and the D-value for this organism at 250F is 0.21 minutes). This process is based on the assumption of the number of surviving spores in one can. If it is assumed that a container had one million spores per can the heat treatment needed to reduce the number to one in one million i.e. from 10^6 to 10^{-12} involves a reduction of twelve decimal places i.e. from 1,000,000 to 0.0000001

6.5.5 F-Value

If we assume that there are 10 surviving spores in one can, then we can calculate the time for a 12-D process to occur by using the following formula:

- $F_0 = D_{250F}$ (log a – log b), where a = initial population and b = final population.
- So F_0 = (0.21min.) (log 10^1 – log 10^{-11}), we move down 12 log values (1 – (–11)) = 12.
- So, F_0 = (0.21min.) (1 – (–11)), or 0.21 × 12 = 2.52 minutes.

Simply put, (D-value at 250F) × (12) results in a 12-D process.

The killing effect of a time / temperature combination is referred to as the **F-value.**

F = 1 is heat killing effect equivalent to 1 min at 121°C.

The F-value required to achieve a 12D cook depends on the resistance of the particular type of bacteria. One of the most resistant species is *Bacillus stearothermophilus* which is 5 or 6 time more resistant than *C. botulinum.*

A 12-D cook for *Cl. botulinum* may require an F value of 2.52
A 12-D cook for *B. stearothermophilus* may require F = 18

From food safety angle, the microorganisms of greatest concern are *Salmonella* sp., *Clostridium perfringens*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Campylobacter sp*., and *E. coli*, all of which have much lower z values and consequently should achieve a 12D process in a shorter time. *Bacillus* of the most heat resistant strains of bacteria known.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why moist heat is a more effective sterilizing agent than dry heat?

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2. Define D-value and Z-value. How these terms are inter-related?

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3. What is the principal of 12D concept?

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4. Define F-value?

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6.6 MICROBIOLOGY OF THERMALLY PROCESSED FOOD

As you can now very well understand the heat is an important way of preserving foods. Still some thermally processed foods undergo spoilage due to chemical or biological reasons. The most important chemical spoilage of canned foods is the hydrogen swell produced as a result of action of food acids with the metals. Biological spoilage of thermally processed foods by microorganisms may result either from the survival of organisms after the heat treatment or leakage of the container permitting entrance of the microorganisms. Surviving organisms may be vegetative cells or spore formers depending upon the heat treatment. Acid foods are processed at temperature around 100^{O}C which result in the killing of all vegetative cells of bacteria, yeasts and molds. Only bacterial spores may survive *stearothermophilus* is a non-pathogenic organism that has been shown to be one but these do not grow in acid foods. On the other hand, meat, vegetables and milk are processed at low temperatures. This may eliminate vegetative cells but not the spores, which germinate later and cause spoilage. Microorganisms that enter through leaks during cooling need not necessarily be heat resistant.

6.6.1 Spoilage by Thermophilic Bacteria

Under processing of low acid foods result in spoilage by thermophilic (microorganisms which require high temperature, more than 45°C for their growth) bacteria such as *Bacillus coagulance, Bacillus stereothermophilus*. These microbes produce heat resistant endospores than can survive 121°C for 4-5 minutes. These organisms produce acid without gas. This is known **as flat sour spoilage**. Some times In Low and medium acid foods the cans swell due to production of carbon dioxide and hydrogen by *Clostridium thermosaccharolyticum*. This is known as **thermophilic spoilage**. **Sulphide spoilage** is caused by *Clostridium nigrificans* in low acid foods. Spores of this bacterium are not very heat resistant and their presence is indicative of under processing. Spoilage is indicated by the the presence of H_2S and blackening of material. Sources of all these material are generally, the plant equipment, sugar, starch, soil etc.

6.6.2 Spoilage by Mesophilic Organisms

Mesophilic microorganisms are those microorganisms which grow best at temperature 25-45°C. Spoilage of canned foods by mesophilic organisms is indicative of under processing and is caused by species of Bacillus, Clostridium, Yeast and fungi. *Clostridium butyricum* and *C. pasteurianum* produce a butyric acid type of fermentation in acid or medium acid foods with swelling of the container by the production of CO_2 and H_2. Other species of *Clostridia* may produce H_2S causing can to swell. These putrefactive anaerobes (Micro organism that grow in the absence of oxygen) generally grow in low acid foods such as peas corn, meat, poultry etc. but some times may also spoil medium acid foods.

Some *Bacilli* such as *Bacillus subtilis* and *B. mesentroides* have been found to grow in poorly evacuated cans of sea foods, meat and milk. The gas forming Bacilli (B.polymyxa, B. macerans) are also reported to cause spoilage of canned peas, spinach, peaches and tomatoes.

The presence of non spore forming bacteria in canned food is an indicative of leak or under processing. *Streptococcus thermophilus*, *Pseudomonas*, *Micrococcus* and *proteus* have also been reported to cause spoilage of thermally processed products. Molds, yeast and their spores are destroyed at pasteurization temperature. Their presence is indicative of under processing or leakage. Spoilage of canned fruits and fruit products by yeasts may result in CO_2 production and spoilage of cans. Film yeast and fungi grow on the surface and cause degradation of the product.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are the probable reasons for biological spoilage of thermally treated foods?

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2. Name two thermophilic microorganisms responsible for flat sour spoilage.

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3. What is thermophilic spoilage?

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4. What do you understand about sulphide spoilage of low acid foods?

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5. Name some mesophilic bacteria responsible for spoilage of thermally treated foods.

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6.7 LET US SUM UP

Thermally processed foods are those that have been i) heated in hermetically sealed container ii) have been filled hot into a container which is then closed and cooled. The purpose of these processes is to destroy pathogenic microorganisms and those that might grow and cause spoilage of the particular food. The food that are commercially sterile are those that will not support microbial growth when exposed to the usual temperatures during storage, transport and marketing. However, they may not be completely free of microorganisms. Pasteurization is heat treatment to inactivate some microorganisms. Thermally processed foods may get spoiled due to under processing or leakage.

6.8 KEY WORDS

Thermophilic : Microorganisms which grow at temperature above 45°C.

Mesophilic : Microorganisms which grow at temperature 25-45°C.

Under processing : Lower time or temperature treatment.

6.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check You Progress Exercise 1

1. Your answer should include the following points:

   - Microorganisms that spoil product are typically called **spoilage organisms**.
   - Microorganisms that can make people sick are **pathogens**.

2. Your answer should include the following points:

   - to keep the food in a stable condition over a period of time
   - to prevent it from spoilage or making people sick.

3. Your answer should include the following points:

   - chemical preservation
   - modified atmospheres
   - irradiation
   - low temperature preservation
   - preservation by drying
   - high temperature preservation.

4. Your answer should include the following points:

   - Time-temperature combination
   - heat penetration characteristics of particular food
   - the type of micro-organisms present in the food material
   - the thermal death time of different microorganisms
   - type of food
   - concentration of the microorganisms
   - state of the microorganism
   - effect of heat on the product
   - the degree of heat penetration
   - food acidity / pH value.

Check You Progress Exercise 2

1. Your answer should include the following points:

   - complete destruction of micro-organisms.

2. Your answer should include the following points:

   - the condition achieved by the application of heat sufficient to render the processed product free from viable microorganisms
   - capable of growing in the food under normal non-refrigerated temperatures at which the food is likely to be held during distribution and storage

- Unlike sterilization here the food is not completely free of microorganisms.

Check You Progress Exercise 3

1. Your answer should include the following points:

   - process created by Louis Pasteur
   - aimed to destroy bacteria, molds, spores etc.
   - discovery about the destruction of bacteria by exposing them to certain minimum temperature for certain minimum time
   - the higher the temperature the shorter the exposure time required.
   - process applied to milk.

2. Your answer should include the following points:

   - Public Health Aspect – to make milk and milk products safe for human consumption by destroying all bacteria that may be harmful to health (pathogens)
   - Keeping Quality Aspect – to improve the keeping quality of milk and milk products. Pasteurization can destroy some undesirable enzymes and many spoilage bacteria. Shelf life can be 7, 10, 14 or up to 16 days.

3. Your answer should include the following point:

   - extent of microbial inactivation depends on the combination of temperature and holding time.

4. Your answer should include the following points:

   - Through pasteurization all of the bacteria are not completely destroyed, it still exists in pasteurized products, but in very low concentrates.
   - Refrigeration keeps the bacteria from further growth, very low.

5. Your answer should include the following points:

   - thermal death time studies for the most heat resistant pathogens found in milk
   - *Coxiella burnetii* and *Mycobacterium tuberculosis* are the most heat resistant non spore forming pathogens.

6. Your answer should include the following points:

   - bacterial destruction is very nearly equivalent in LTLT and in HTST pasteurization processes but
   - HTST treatment give the best quality products in respect of flavour and vitamin retention.

Check You Progress Exercise 4

1. Your answer should include the following points:

   - moisture increases the rate of heat penetration.
   - Moist heat requires less heat (temperature or time) than dry heat
   - 121°C for 10 min of moist heat is equivalent to about 30 min at 200°C of dry heat.

2. Your answer should include the following points:

   - D-value is the amount of time that it takes at a certain temperature to kill 90% of the organisms being studied.
   - Z value is defined as the temperature change required to change the D-value by a factor of 10.
   - D-value gives us the time needed at a certain temperature to kill an organism
   - Z-value relates the resistance of an organism to differing temperatures.

3. Your answer should include the following points:

   - process based on the assumption of the number of surviving spores in one can.
   - canned foods subjected to a time/temperature process that will reduce the probability of the survival of the most heat-resistant *C. botulinum* spores by 12 logs i.e. from 1,000,000 to 0.0000001.

4. Your answer should include the following point:

   - killing effect of a time / temperature combination.

Check You Progress Exercise 5

1. Your answer should include the following point:

   - Under processing or leakage may be the cause of spoilage of thermally treated foods.

2. Your answer should include the following point:

   - *Bacillus coagulance* and *Bacillus stereothermophilus.*

3. Your answer should include the following point:

   - In Low and medium acid foods the cans swell due to production of carbon di oxide and Hydrogen by *Clostridium thermosaccharolyticum*.

4. Your answer should include the following points:

   - caused by *Clostridium nigrificans* in low acid foods.
   - Spores of *Clostridium nigrificans* are not very heat resistant and their presence is indicative of under processing.

- Spoilage is indicated by the the presence of H_2S and blackening of material.
- Sources of all these material are generally, the plant equipment, sugar, starch, soil etc.

5. Your answer should include the following points:

- *Clostridium nigrificans*
- *C. pasteurianum*
- *Bacillus subtilis*
- *B. mesentroides*
- *B.polymyxa*
- *B. macerans*
- *Streptococcus thermophilus*
- *Pseudomonas*
- *Micrococcus* and *Proteus.*

6.10 SOME USEFUL BOOKS

1. Adams, M.R. and Moss, M.O. (2000) Food Microbiology. Royal Society of Chemistry, Cambridge, U.K.

2. Jay, J.M. (2000) Modern Food Microbiology, Van Nostrand Company, New York.

UNIT 7 DRYING – CONTROLING OF MICROORGANISMS

Structure

7.0 OBJECTIVES

After studying this unit, you should be able to:

- know the importance of dehydrated fruits and vegetables;
- have an idea about the drying/dehydration theories of fruits and vegetables;
- have the knowledge about the microorganisms evolved in dried products;
- know the different kinds of microorganism associated with dried foods; and
- know about the microbial spoilage of dried fruits and vegetable products.

7.1 INTRODUCTION

Drying or dehydration is accomplished by the removal of water from the fruits and vegetables below a certain level at which enzyme activity and growth of microorganisms is affected adversely. The dried fruits and vegetable are called as high sugar high acid foods or high value low volume foods. These dried or concentrated products save energy, money and space in shipping, packaging, storing and transportation. Dehydration or drying process usually involves heating, in which water is removed from solid or near solid substances. The term **drying** is generally used for drying of the produce under the influence of non-conventional energy sources like sun and wind. **Dehydration** on the other hand refers to the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and air flow. The sun drying is a slow process and thus, not suitable for many high quality products. Generally, it lowers the moisture contents below about 15% which is too high for storage stability of numerous products.

7.2 PRINCIPLES

The basic principle in the process of drying or dehydration is the removal of sufficient moisture to protect the product from spoilage. The process reduces the amount of available moisture i.e. the water activity (a_w) and hence, product becomes shelf-stable and is preserved for quite a long period. Moisture-solid, relationship in fruits and vegetables are more complex than in inorganic materials as the matter in fruits and vegetables exhibits an energetic retention of moisture and the moisture is bound to the solid. The solid skeleton consists essentially of numerous cells joined together to provide a network of capillaries, some of them are very fine. First the moisture in the larger capillaries has to be evaporated then only the moisture in the finer capillaries can be removed. The cell walls act as semi-permeable membranes for the diffusion of moisture which is mainly held osmotic ally. Finally, there is a small amount of moisture adsorbed on the skeletal frame in multi molecular layers. In order to dehydrate any product specific requirements need to be fulfilled so that the product retains as much as possible, its original characteristics.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you mean by drying and dehydration?

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2. What are the main objective of drying?

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3. What is the role of air in the process of drying or dehydration?

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4. How the fruits & vegetables are more complex than inorganic?

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7.3 MECHANISM OF DEHYDRATION

The changes during dehydration can be largely explained in terms of heat and mass transfer phenomena. A cue of food in the course of dehydration loses moisture from its surface and develops dried layer with remaining moisture confined to its centre. From the centre to the surface a moisture gradient will be stabilized. The outside dried layer acts as an insulation barrier against rapid heat transfer into the food pieces, this is further decreased by air voids formed by evaporating water. In addition to less driving force from decreased heat transfer, the centrally remaining water also now has further to travel to get out of the food piece than did surface moisture at the start of drying. In addition, as the food dries it approaches its normal equilibrium relative humidity, as it does; it begins to pick up molecules of water vapour from the drying atmosphere as fast as it loses them. When these rates are equal drying ceases.

7.4 THEORY OF DRYING

There are two steps involved in drying & dehydration.

7.4.1 Heat Transfer Theory

Transfer of heat consists of transferring of molecular or atomic motion from one region to another. There are three broad mechanisms by which such transfer can occur, conduction, convection, and radiation. In conduction, the energy is transmitted from particle to particle by a process of direct contact. Transfer of heat by convection involves bulk mixing of fluids of different temperatures. Radiation is the transfer of energy from a radiating source through space which may or may not be occupied by matter. It is by radiation that we receive all our energy from the sun.

7.4.2 Mass Transfer Theory

The removal of moisture from a food product involves simultaneous heat and mass transfer. Heat transfer occurs within the product structure and is related to the temperature gradient between the product surface and the water surface at some location within the product. As sufficient thermal energy is added to the water to cause evaporation, the vapours are transported from the water surface within the product to the product surface. The gradient causing moisture –vapour diffusion is vapour pressure at the liquid water surface, as compared with the vapour presser of air at the product surface. The heat and the mass transfer within the product structure occurs at the molecular level, with heat transfer being limited by thermal conductivity of the product structure, while mass transfer is proportional to the molecular diffusion of water vapour in air. The rate of moisture diffusion can be estimated by the expression for molecular diffusion. The mass flux for moisture movement is a function of the vapour pressure gradient as well as the mass diffusion for water vapour in air, the distance for water vapour movement within the product structure and temperature. The transport of vapour from the product surface to the air and the transfer of heat from the air to the product surface is a function of the existing vapour pressure and temperature gradients, respectively, and the magnitude of the convective coefficient at the product surface.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. In the food product how the changes are occurred.

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2. What are the main mechanisms by which heat can transfer?

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3. How the evaporation is occurred during drying?

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4. What are the functions of vapour pressure and temperature gradient?

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7.5 IMPORTANCE OF WATER ACTIVITY (a_w)

Water activity (a_w) is defined as the ratio of the vapour on the aqueous solution to that of pure water at the same temperature i.e.

a_w = Vapour pressure of solution at T°C

Vapour pressure of pure water at T°C.

Water activity is also equal to the equilibrium relative humidity (ERH);

$$a_w = \frac{\text{Equilibrium relative humidity}}{100}$$

The a_w has a major role to play in microbiological spoilage and chemical changes produced in the food. The principles of water and microorganisms relation includes:

1) Water activity, rather than water content, determines the lower limit of available water for microbial growth. Most bacteria do not grow below a_w 0.91 and most molds cease to grow at water activity of 0.80. Some xerophylic fungi have been reported to grow at water activities of 0.65, but the range of 0.70 – 0.75 is generally considered their lower limit.

2) Environmental factors affect the level of water activity required for microbial growth. The less favourable the other environmental factors (nutrients, pH, oxygen pressure, temperature) the higher becomes the minimum a_w at which microorganisms can grow.

3) Some adaptation to low water activities occurs, particularly when a_w is depressed by addition of water soluble substances (principle of IMF – Intermediate Moisture Food), rather than by water crystallization (frozen foods) or water removal (dehydrated foods).

4) When water activity is depressed by solutes. The solutes themselves may have effects which complicate the effect of a_w per se. For instance, at a given a_W microbial growth is less effectively depressed by glycerol than by sodium chloride. More recent (IMF – Intermediate Moisture Food) have resulted in the following additional findings.

   a) Water activity modifies sensitivity of microorganisms to heat, light and chemicals. In general organisms are most sensitive at high water activities (i.e. in dilute solution) and minimum sensitivity occur in an intermediate moisture. Minimum water activities for production of toxins are often higher than those for microbial growth. The phenomenon may represent an important safety factor in the distribution of dehydrated and intermediate moisture foods.

   b) The effect of water on chemical reactions in foods are more complicated than are its effect on microbial growth. It plays one or more of the following roles; a) as a solvent for reactant and for products, b) as a reactant (e.g. in hydrolysis reactions) c) as a product of reactions and d) as a modifier of the catalytic or inhibiting activities of other substances (e.g. water in activities some metallic catalysts of lipid per oxidation).

All microorganisms have an optimal and minimal water activity for growth. Adjusting the a_w of a product by addition of solutes or the removal of water, to a point below the minimal a_w of the normal spoilage flora results in a microbiological stable product. Many of the products contain viable microorganisms and spores, which are not able to germinate because of the restrictative a_w. In fabrication of a product with a reduced a_w other factors which would affect the growth of microorganisms present need to be considered, since the a_w on microorganisms is influenced by pH, oxygen level, temperature, nutrient content, and possibly food preservative, either natural or added.

Water activity (a_w) influences the physical, chemical and microbiological properties of many substances. The shelf life of foods, their colour, stability, taste, texture, vitamin content, aroma, mold formation and microbiological growth properties are influenced directly by the a_w value. a_w measurement is required to meet standards like FDA – Food Drug Act, USDA – United State Department of Agriculture, GMP – General Manufacturing Practices, HACCP – Hazard Analysis and Critical Control Points, and BIS 15000 – Bureau of Indian Standards: The foods types and range of a_w is discussed as given below.

A_w range	**Upper limit values for micro-organisms**	**Foods in this range**
1.00-0.95	*Pseudomonas, Escherichia, Proteus, Shigella, Clesiella, Bacillus, Clostridium, perfringens*, some yeast	Perishable (fresh) food and fruit in tins, Vegetables, meat, fish and milk, cooked sausage, backed bread, food with a content up to 40% weight sucrose or 7% common salt.
0.95-0.91	*Salmonella, Vibrio parahaemoliticus, C. botulinum*, Serratia, *Lactobacillus, Pediococcus*, some mold, yeast	Some cheese (cheddar, Swiss, Muenster, and Provolone) smoked meat (ham) some fruit juice concentrates, food with a 55% weight sucrose (saturated) or 12% common salt.
0.91-0.87	Many types of yeast *(Candida, Torulopsis, Hansenula), Micrococcus*	Matured sausages (salami), cake, dry chesses, margarine, and food with a 65% weight sucrose (saturated) or 15% common salt.
0.87-0.80	Most types of mold (mycotoxic *Penicillia*), *Staphylococcus aureus*, most *Saccharomyces* (bialii) spp. , *Deboryamyces*	Most fruit juice concentrates, sweetened milk, chocolate syrup, maple and fruit syrup, flour, rice, pulses with a water content 15-17%, fruit cakes traditional smoked hams.
0.80-0.75	Most types hallophilic bacteria, mycotoxic aspergilli	Marmalade, jam, fruit jelly, marzipan, glace fruit, some types of marshmallow.
0.75-0.65	Xerophylic mold *(Aspergillus chevalier, A. candid us, Wallemia semi), Saccharomyces bisporus*	Rolled oats with a 10% water content, naught, fondant, marshmallows, grouts, molasses, raw sugar, some dried fruit, and nuts.

0.65-0.60	Osmophyilc yeast *(Saccharomyces rouxi)*, some mould *(Aspergillums echinulatus, Monascus bisporus)*	Dried fruit with 15-20% water content, some types of toffee, caramel, honey
0.5		Noodles, Spaghetti, pasta. etc. with about 12% water content, spices with about 10% water content
		Egg powder with about 5% water content
0.4	No microbial growth	
0.3		Biscuits, crackers, bread crust, cookies, etc. with about 3-5% water content
0.2		Powder milk with about 2-3% water content, dried vegetables/ fruit with about 5% water content, cornflakes with about 5% water content fruit cake, rustic, crackers, biscuits

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name some of products which have the a_w between 0.65-0.60.

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2. Name the microorganisms which are found at a_w between 0. 65-0.60.

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7.6 MICROORGANISMS ASSOCIATED WITH DRIED FRUITS AND VEGETABLES

Microorganisms are associated, in a variety of ways, with all of the food we eat. They may influence the quality, availability, and quantity of our food. Naturally occurring foods such as fruits and vegetables normally contain some microorganisms, and may be contaminated with additional organisms during handling. Food serves as a medium for the growth of microorganisms, and this growth may cause the food to undergo decomposition and spoilage. Food may also carry pathogenic microorganisms and as a result transmit diseases. Dried foods has been used for centuries and they are more common throughout the world than frozen foods. Growth of all microorganisms can be prevented by reducing the moisture content of their environment below a critical level. The critical level of moisture is determined by the characteristics of the particular organisms and the capacity of the food item to bind water so that it is not available as free moisture.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. In what way microorganisms affect the products.

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2. How the growth of microorganisms can be arrested.

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7.7 MICROBIOLOGY OF FRUITS AND VEGETABLE

7.7.1 Microbiology of Fresh Fruits and Vegetables

Fruits and vegetables are normally susceptible to infection by bacteria, fungi and viruses. Microbial invasion of plant tissue can occur during various stages of fruits and vegetables development and hence to the extent that the tissues are infected the likelihood of spoilage is increased. A second factor contributing to the microbial contamination of fruits and vegetables pertains to their post harvest handling. Mechanical handling is likely to produce breaks in the tissue which facilitates invasion by microorganisms. The pH of fruits is relatively acid ranging from 2-3 for lemons to 5.0 for bananas. This resists bacterial growth but does not retard fungal growth. The range for vegetables is slightly higher pH 5.0 to 7.0 and hence they are more susceptible than fruits to attack by bacteria.

7.7.2 Microbiology of Dried Fruits and Vegetables

The microorganisms on most of the dried fruits vary a few hundred per gram of fruits to thousands, and in whole fruits they are mostly on the outer surfaces. Spores of bacteria and molds are likely to be most numerous. When part of the fruit has supported growth and sporulation of mold before or after drying, mold spores may be present in large numbers. The number on the vegetable just before drying may be high because of contamination and growth after blanching and the percentage killed by the dehydrating process usually is less than with the more acid fruits. If drying trays are improperly loaded, souring of such vegetables as onions or potatoes by lactic acid bacteria with marked increase in number of bacteria which may take place during the drying process. The risk may be grater of the fruits and vegetables which are not blanched before drying like onion. Microbial counts on dried vegetables range from negligible to millions per gram. A number of genera of bacteria found on dried vegetables includes: *Escherichia, Enterobactor, Bacillus, Clostridium, Micrococcus, Pseudomonas, Streptococcus, Lactobacillus and Leuconostoc*. Of these, *Lactobacillus* and *Leuconostoc* species are predominant in many samples of dehydrated vegetables.

Dried fruits become musty of molds and dried vegetables soft or slimy if kept in a damp atmosphere in unsealed containers. Hence, proper sealing and storing of containers at ambient temperature and in a dry place is important. Dried fruits and vegetables should be packed in moisture proof containers. Higher density polythene (HDP) package of multiple aluminium foil are utilized for packing of dried vegetables.

The bacteria, such as *Bacillus* sp., *Clostridium* sp., *Micrococcus* sp, *Streptococcus* sp., and *Pseudomonas* sp. are common as soil and water born. Bacteria capable of causing food poisoning such as *Salmonella* sp. and *Clostridium botulinum*, are not found in dehydrated foods as in case of dehydrated onion where the microbial load is influenced by the following factors:

1. The load and types of microorganism present on the raw material.
2. Pre-treatment given to the material
3. Time lag between preparation and dehydration
4. Drying time and temperature
5. Moisture content of the finished product
6. In plant sanitation,
7. Packaging and storage conditions of the finished product.

One of the important types of microbiological spoilage in onion during dehydration is fermentation and souring, which are undesirable and make the product sub-standard. Sour onions have characteristics sour taste commonly associated with vegetable tissues undergoing lactic acid fermentation. Onion slices do not dry properly. Pink discolouration and off taste are indications of spoilage. Bacteria which predominate in fresh onions include representatives of the genera: *Lactobacillus*, and *Aerobactor*. Fresh onions juice sterilized by filtration suppressed the growth of *Bacillus* subtilis and *E. coli*. but did not prevent the growth of *Lactobacillus brevis* and *Aerobactor aerogens*. In good quality of dehydrated onion many aerobic bacilli and other soil and water born bacteria are not found which may be due to the toxicity of constituents present in fresh onions.

To check the souring and fermentation as well as to reduce the microbial load to the minimum the following points should be closely watched:

1. Onion bulbs selected for dehydration should be free from disease and blemish

2. Onions should be thoroughly washed after peeling in 3-5 ppm chlorine water.

3. The cut slices should be dried immediately under controlled conditions so that the finish product can be obtained in the minimum time having moisture at 6-7 percent.

4. Sanitary conditions and workers hygiene in the factory should be controlled and

5. Proper packing room facilities and nitrogen gas packaging are important for the storage of finished product

The number of microorganisms and their kinds vary at different stages of processing such as

7.7.3 Before Reception at the Processing Plant

The microbiology of foods before their reception at the processing plant is likely to be similar whether the foods are to be dried, chilled, frozen, canned or otherwise processed. Fruits and vegetables have soil and water organisms on them when harvested, plus their own natural surface flora and spoiled parts contain the microorganisms causing the spoilage. Growth of some of these organisms may take place before the foods reach the processing plant if environmental conditions permit. Thus piled vegetables may raise temperature and stimulate the growth of slime- forming, flavour harming, or even rot-producing organisms.

7.7.4 In the Plant before Drying

Growth of microorganisms that begun on foods before they have reached the drying unit may continue up to time of drying. Also equipment and workers may contaminate the food. Some of the pre-treatment reduce number of organisms while other may increase them, but the foods may be contaminated after these treatments. The grading, selection, and sorting of fruits and vegetables, influences kinds and number of microorganisms. The elimination of spoiled fruits and vegetables or of spoiled parts reduced number of organisms in the product to be dried.

Washing of fruits and vegetables removes soil and other adhering materials and serves to remove microorganisms. There also possibility of adding organisms if the water is of poor quality.

Peeling fruits or vegetables, especially with steam or lye, and slicing or cutting reduces the number of organisms if equipment is adequately cleaned and sterilized.

Dipping in dilute alkali as applied to certain fruits before sun drying may reduce the microbial population.

Blanching or scalding vegetables reduces the bacterial numbers greatly, as much as 99 percent in some instances. Sulphuring of fruits and vegetables also causes a great reduction in number of microorganisms and serves to inhibit growth in the dried product.

7.7.5 During the Drying Process

Heat applied during a drying process causes a reduction in total number of microorganisms, but the effectiveness varies with the kinds and numbers of organisms originally present and the drying process employed. Usually all yeasts and most bacteria are destroyed, but spors of bacteria and molds commonly survives, as do vegetative cells of a few species of heat resistant bacteria, improper conditions during drying may even permit the growth of microorganisms. More microorganisms are killed by freezing than by dehydration during the freezing- drying process.

7.7.6 After Drying

If the drying process and storage conditions are adequate there will be no growth of microorganisms in the dried foods. During storage there is a slow decrease in number of organisms, the microorganisms that are resistant to drying will survive best: therefore the percentages of such organisms will increase. Especially resistant to storage under dry conditions are the spores of bacteria and molds, some of the micrococci, and micro bacteria. There may be some opportunity for contamination of the dried food during packaging and other handling subsequent to drying.

Special treatment given to some dry foods will influence microbial numbers e.g. sweating of dry fruits to equalize moisture may permit some microbial growth. Pasteurization of dry fruits will reduce number of microorganisms. Some products are re-packaged for retail sale, e.g. figs in the near east, are subjected to contamination. The microbial content and the temperature of water used to rehydrate for dried foods also affect the number of microorganisms if rehydration done in water at 50°C the number of microorganisms will be more and number of microorganisms is almost eliminated when the product is rehydrated at 85 to 100°C.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write the name of microorganisms which spoil attack to the fruits and vegetables.

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2. What are the factors which affect the microbial load in the finished products?

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3. Write few points which help to check the incidence of souring, fermentation, and microbial load.

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4. What are the factors which reduce the microorganisms in fresh fruits and vegetables?

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5. Write few treatments which given to dehydrated fruits for control of microorganisms.

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7.8 SURVIVAL OF MICROORGANISMS IN DRIED FOODS

The survival of microorganisms in dried foods can be markedly affected by a_w level. There are important interaction between a_w and such factors as pH, oxygen and food composition. For many foods, deterioration during storage in the dry state is least at the relatively low a_w levels. Survival of pure cultures of vegetative bacteria equilibrated to a range of a_w levels after freeze drying have shown clearly the increase in survival that accompanies reduction in a_w level to 0.1 -0.2. Survival of *Salmonella newport* at 0.0 a_w, after freeze –drying in papain digest, was nearly maximum in vacuum, but was very poor when stored in air. Although *Pseudomonas fluorescense* proved more susceptible to death on storage, the qualitative response to a_w was similar. Death of bacteria during storage at reduced a_w levels is greatly influenced by the nature of solution from which they had been dried.

7.8.1 Survival at Freezing Temperatures

Freezing and frozen storage may reduce greatly the viability of populations of sensitive microorganisms. The latter include the vegetative cells of yeasts and molds and most gram negative bacteria. Gram positive bacteria, especially cocci, are more resistant, and for these reasons enterococci are frequently claimed to be more suitable than *Escherichia coli* as indicators of fecal contamination in frozen foods. Many fungal spores also show this level of resistance, however bacterial spores are least affected by freezing.

The rate of freezing influences the survival, because of it influence the size of ice crystals and hence the degree of mechanical damage caused to cellular structures. Rapid freezing is less damaging than slow freezing. It is the range of temperature between freezing point of a food and its eutectic, influences the a_w of food, but not its overall solute concentration. The eutectic means that the solute remain in equilibrium in frozen food. A frozen food held at -20^{o}C has an a_w of 0.823, irrespective of its composition. Although composition of food does not control a_w, it can have a marked influence on survival of microorganisms frozen in food. Sugars, sugar alcohol, glycols, and proteins, may have protective effect. The added sucrose have effect on the survival of *Torula* sp. in frozen orange juice.

7.8.2 Survival at Moderate Temperatures

Many sterile foods are microbiologically stable in the moderate or room temperature range. The majority of dried or concentrated foods, owe their stability to reduced level of a_w. However, if rehydrated before consumption, regain the ability to support microbial growth, so that the capacity of contaminating organisms to survive the period of low a_w storage is of obvious relevance. Studies on survival of pure cultures of vegetative bacteria equilibrated to range of a_w levels after freeze drying have shown clearly the increase in survival that accompanies reduction in a_w level to 0.1-0.2. In dried foods the bacteria during storage at reduced a_w levels is greatly influenced by the nature of solution from which they had been dried. While non-reducing sugars are protective, and reducing sugars accelerate bacterial inactivation.

7.8.3 Survival at Elevated Temperatures

Microorganisms vary in heat resistance, the more resistant bacteria (e.g. *Bacillus stearothermophillus*) producing spores with decimal reduction times in neutral foods as long as 4 minutes at 121°C. or 40 minutes at 110°C. Yeast ascospores are only slightly more heat resistant than vegetative yeast cells. The qualitative effect of moisture upon microbial heat resistant is well known-moist heat is a much more effective sterilizing agent than dry heat and, wherever, practicable, steam sterilization is preferred as being much more rapid than hot air (dry) sterilizing. Water activity is also likely to be significance in the heat treatment of foods in the intermediate moisture range, Pasteurization temperature for salmonellae, staphylococci, and yeast (50-60°C) death rates are lowest in the a_w range 0.75- 0.85 in glycerol adjusted solutions. Osmophilic yeasts respond similarly to salmonellae when heated in sucrose solution with decimal reduction times increasing as a_w decreases from 0.995 to 0.85. These organisms are more heat sensitive than salmonellae.

7.9 MICROBIAL SPOILAGE OF DRIED FOODS

Spoilage of dried fruits and vegetables by insects

The presence of water in fruits and vegetables is mandatory to undergo microbial spoilage. All organisms require water for carrying on their life processes. If the microorganisms cannot acquire the water it either dies or its further growth is arrested. Potential spoilage of a dried fruit, then depends upon how available water is to the spoilage microorganisms, It is therefore the thin demarcation line of water activity which establishes dehydration as a good preservative techniques. The degree to which water is available to the microorganisms is expressed by the term water activity, (a_w,) that is the vapour pressure of the solution divided by the vapour of the solvent.

Removing the water from the fruit and vegetables is to reduce its availability to the microorganisms. In a moist solid substance , the water vapour pressure is lower than the vapour pressure of free water at the same temperature because, in a solid substance, water reacts with polar group such as –CO -, -NH, -OH. Still further vapour pressure inside of capillaries (between plant cells) is lower than the vapour pressure of a plane surface of water. As the solutes present in the fruit are dissolved in water the vapour pressure is depressed. Certain osmophilic yeasts and certain xerophilic molds and fungi are able to live and proliferate at water activities of low values. These are the microorganisms responsible for the spoilage of dried fruit and vegetables. Bacterial growth of generally impossible when a_w is reduced below 0.90. The growth of normal yeast is generally impossible when the a_w is reduced below 0.88. The growth of normal molds is generally impossible below 0.80. Each organism has its own characteristics optimum a_w at which growth will occur. Molds are the most troublesome group of microorganisms will grow at a_w values below 0.70.

Dried fruits and vegetables are also subjected to insect attack when not dried and stored properly. Insect not only consume food stuffs but also leave much debris which spoils the appearance of the product. These insect can be killed either by heating or by fumigation. In heat treatment, dried fruits are dipped in boiling water or in dilute solution of salt (NaCl) –$NaHCO_3$) and then, redried at 54-65°C. Dried vegetables may be heated directly without preliminary dipping. Fumigation with ethylene oxide inside the storage chamber also reduces attack by insects.

Dried fruits become musty or moldy and dried vegetables soft or slimy if kept in a damp atmosphere in unsealed containers. Hence, proper sealing and storing of containers at ambient temperature and in a dry place is important.

Dehydrated fruits and vegetable potential defects and means to prevent them are given below:

Defects	**Causes**	**Prevention**
Molding	High product moisture, above equilibrium relative humidity corresponding to water activity a_{w} = 0.70.	Reduce water content down to optimum values, pack in hermitic air tight package.
Infestation	Presence in dried products of larva or insects.	Storage room disinfection with toxic gases. Fumigation of packed products and of packages. Disinfection

		by heat (60-65°C) of products before packing.

Considering the variety of natural food substances and the methods by which each is handled during processing , it is apparent that practically all kinds of microorganisms are potential contaminants. The type of food substance and the method by which it processed and preserved may favour contamination by certain groups of microorganisms. Most foodstuffs serve as good media for the growth of many different microorganisms, and microorganisms' changes in appearance, flavour odor, and other qualities of foods. These degradation processes may be descrived as follow;

Putrefaction

Protein foods + proteolytic microorganisms → amino acids + amines = ammonia + hydrogen sulphide.

Fermentation

Carbohydrate foods + carbohydrate-fermenting microorganisms → acids = alcohol = gases.

Rancidity

Fatty foods + lipolytic microorganisms→ fatty acids = glycerol.

Some microorganisms discolour foods as a result of pigment production. Slimes may be developed in or on foods by microorganisms capable of synthesizing certain polysaccharides.

Check Your Progress Exercise 6

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. At low moisture content how the growth of microorganisms is check.

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2. List the microorganisms which are responsible to spoil the dried fruits and vegetables.

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3. Write the level of a_w at which the growth of bacterial, yeast and mould is impossible.

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4. What are the changes occur in the food products when they are attack by microorganisms.

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7.10 LET US SUM UP

The reduction in weight and bulk by drying and dehydration of the commodity can result in economies in cost of containers, shipping and distribution of dehydrated products. The dehydration also result in the production of convenience products e.g. instant coffee instant milk and instant mashed potatoes. The production of dried fruits and vegetable products are less costly as there is a minimum of labour and processing equipment required. These products also require less space for storage then fresh canned or frozen fruits and vegetables.

Microorganisms are associated, in a variety of ways, with all of the food we eat. They may influence the quality, and availability of our food. Naturally occurring foods such as fruits and vegetables normally contain some microorganisms, and may be contaminated with additional organisms during handling. Food can serve as a medium for the growth of microorganisms, and this growth may cause the food to undergo decomposition and spoilage. The microorganisms on most of the dried fruits vary a few hundred per gram of fruits to thousands, and in whole fruits they are mostly on the outer surfaces. Spores of bacteria and molds are likely to be most numerous. When part of the fruit has supported growth and speculation of mold before or after drying, mold spores may be present in large numbers. Microbial counts on dried vegetables range from negligible to millions per gram. A number of genera of bacteria found on dried vegetables includes: *Escherichia, Enterobactor, bacillus, Clostridium, Micrococcus, Pseudomonas, Streptococcus, Lactobacillus* and *Leuconostoc*. Of these, *Lactobacillus* and *Leuconostoc* species are predominant in many samples of dehydrated vegetables.

Water activity (a_w) influences the physical, chemical and microbiological properties of many substances. The shelf life of foods, their colour, stability, taste, texture, vitamin content, aroma, mold formation and microbiological growth properties are influenced directly by the a_w value. The survival of microorganisms in dried foods can be markedly affected by a_w level, there are important interaction between a_w and such factors as pH, oxygen and food composition. Certain osmophilic yeasts and certain xerophilic molds and fungi are able to live and proliferate at water activities of low values. These microorganisms are responsible when water activity (a_w) is reduced below 0.88, and the growth of normal yeast is generally impossible below the water activity (a_w) of 0.88.

7.11 KEY WORDS

Water activity : Water activity (a_w) is the ratio of vapour pressure of food (P) and pure water (p_o) and expressed by aw = p/p_o.

Dehydration : Removal of moisture under controlled conditions of temperature, air flow and humidity.

Drying : Drying of the product under the source of non-conventional energy sources like sun and wind.

Blanching : Partial pre-treatment in which vegetables are heated in water or in steam to inactivate enzyme before processing.

Sulphuring : Exposing the fruits to the fumes of burning sulphure inside of closed chamber.

In-package desiccant	:	Packaging of the dried products with a material like calcium oxide or silica gel.
Sorption isotherms	:	Water sorption isotherms is a graphical presentation of data which shows the water relationship of food.
Preservation	:	Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutritive and free from and microbial infection.
ERH	:	Equilibrium Relative Humidity.
Osmotic dehydration	:	Removal of water through a membrane from higher concentration to lower concentration.
Sweating	:	Process for holding the dried fruits and vegetables in to bins or package for equalization of moisture
Pasteurization	:	Pasteurization of fruits and vegetable products by heat process below 100°C.
Rancidity	:	Discolouration of food products.
Processing	:	The application of heat to the fruit and vegetables after hermetic (air tight) sealing in containers is called the processing.
Spoilage	:	The food which has been damaged or injured which make the food undesirable for human use.
Rehydration ratio	:	Reconstitution ratio is the quantity of water replaced by dehydrated foods.
Reverse osmosis	:	Reverse osmosis means movement of water through the membrane by applying pressure on the solute side of the membrane in excesses of the osmotic pressure.

7.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Drying of commodity in the sun with non conventional sources of energy like sun and wind is called drying.
   - Drying the commodity under controlled conditions like temperature, relative humidity and air flow is called dehydration.

2. Your answer should include the following points:

   - To reduce the weight and bulk.
   - To reduce the water activity.

3. Your answer should include the following points:

   - To convey the heat to the product.
   - To let out the moisture from the product.

4. Your answer should include the following points:

   - They exhibits an energetic retention of moisture.
   - They bound the moisture to the solid content.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Due to heat transfer to the product.
   - Due to mass transfer out the product.

2. Your answer should include the following points:

   - Heat transfer through conduction.
   - Heat transfer through convection.
   - Heat transfer through radiation.

3. Your answer should include the following points:

   - By addition of thermal energy to the product.
   - By transfer the heat to the product and water surface.

4. Your answer should include the following points:

   - Transfer of vapour from product surface to the air.
   - Transfer of heat from the air to the product.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Dried fruits
   - Some types of toffee
   - Honey

2. Your answer should include the following points:

   - Osmophyile yeast
   - *Aspergillus echinulatus*
   - *Monascus bisporus*

Check Your Progress Exercise 4

1. Your answer should include the following points:

   - In the form of quality
   - In the form of availability
   - In the form of quantity

2. Your answer should include the following points:

   - By reduce the moisture content of the product.
   - By reduce the moisture content of their environment below critical level.

Check Your Progress Exercise 5

1. Your answer should include the following points:

   - Some of bacteria
   - Some of fungi
   - Some of viruses

2. Your answer should include the following points:

   - Load and types of microorganisms in raw material.
   - Time leg between preparation and drying.
   - Moisture content in the finished product.

3. Your answer should include the following points:

   - Bulbs should be free from diseases and blemish
   - Dried the cut slices immediately under control condition
   - Pack and stored under proper conditions

4. Your answer should include the following points:

   - Grading
   - Selection
   - Sorting

5. Your answer should include the following points:

   - Sweating
   - Pasteurization

Check Your Progress Exercise 6

1. Your answer should include the following points:

   - By arrest the growth of the microorganisms.
   - By destroys the microorganisms.

2 Your answer should include the following points:

   - Osmophilic yeast
   - Xerophilic molds
   - Fungi

3. Your answer should include the following points:

   - For bacterial growth a_w below, 0.90

- For yeast the a_w below , 0.88
- For mold growth the a_w below, 0.80

4. Your answer should include the following points:

   - Changes in appearance
   - Changes in flavour
   - Changes in odor
   - Changes in quality

7.13 SOME USEFUL BOOKS

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UNIT 8 CHEMICALS FOR CONTROLING MICROORGANISMS

Structure

8.0 OBJECTIVES

This unit introduces you to the concept of preservation of food with chemicals. After going through this unit you will be able to know how chemical reactions causing spoilage are prevented or delayed by use a wide range of chemical additives.

After studying this unit, you should be able to:

- know the various classes of chemical additives used in the food industry;
- explain how these chemicals help to prevent the spoilage of food;
- know the permitted and non permitted chemical additives;
- discuss the general considerations required in the selection of food preservatives; and
- that apart from certain added preservatives there are some naturally occurring preservative factors in food.

8.1 INTRODUCTION

In Unit 1, you read about the various types of microorganisms that are important in the food industry. In this unit, we shall tell you how the spoilage of food can be prevented or delayed which are caused due to these microorganisms or some other chemical reactions. This unit highlights the various classes of chemical preservatives that have been approved for the use in food and their use. The various aspects to be considered for the selection of chemical additives (food additives), their mode of action and the adverse reactions resulting due to the consumption of the additives is also elaborated in this unit. The unit also deals with the developed additives, namely acids, alcohol and bacteriocins.

8.2 USES OF VARIOUS FOOD ADDITIVES AND CHEMICAL PRESERVATIVES

For centuries, man has recognized the effects of food additives and has used whatever was available-marigold for colour, wood ashes for leavening, the lining of calf stomachs for cheese making etc. today, thousands of compounds are used as food additives, whose chemical identity and structure are known. The use of food additives is imperative in the complex and integrated society in which we live. Additives have provided protection against food spoilage during storage, transportation, distribution or processing. Also, with the present degree of urbanization, it would be impossible to maintain food distribution without the processing and packing and packing with which many additives are involved.

Additives permit the variety of foods that we deem desirable and which certainly are objectively important in maintaining important nutrition. Vitamins and minerals are important in maintaining good nutrition. Many of these chemical additives can be manufactured so that foods can be “fortified” or “enriched”.

There is then the need for the use of food additives to maintain the nutritional quality of food, to enhance the stability with resulting reduction in waste, to make food more attractive and to provide efficient aids in processing, packing and transport. The amount of food additives used should be kept to a minimum and it should conform to a standard of purity and be safe. Over 3000 different chemical compounds are used as food additives. They are categorized into different groups which will be discussed below.

According to WHO a food additive is defined as a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging. The term does not include chance contaminants- thus the former refers to intentional food additive while latter is incidental un-intentional food additive.

Intentional food additives could be nutritive, freshness maintenance, sensory and processing aids; preservatives, antioxidants, emulsifiers, stabilizers, maturing agents, colours, special sweeteners, nutrient supplements, flavouring compounds and natural flavouring materials.

8.2.1 Types of Additives

- ***Acidity regulators***, used to alter and control the acidity or alkalinity levels for different desired effects, which can include preservation, added/altered tartness, colour retention and to assist raising agents.

- ***Acids***, used to control to what degree other substances function and/or to impart a sharp taste. Assists in the release of carbon dioxide in raising agents and can have a preservative effect.

- ***Anti-caking agents***, used to ensure the free flow in products such as dried milks, icing sugar and table salt.
- ***Anti-foaming agents***, used to reduce or prevent foaming (frothing) on boiling and to reduce scum forming.
- ***Antioxidants***, used to protect food against deterioration caused by exposure to air (oxidation), such as fat rancidity, flavour deterioration or colour changes.
- ***Bleaching agents***, used to artificially whiten flour.
- ***Buffers***, see acidity regulators.
- ***Bulking agents***, used to increase volume without significantly adding to the energy levels of the food. Normally used in diet foods but can also be used to pad out expensive ingredients. Not usually digested and acts as a source of dietary fibre (roughage).
- ***Carriers and carrier solvents***, used to modify a food additive (by dissolving, diluting or dispersing etc.), without changing its function, to enable easier use or handling.
- ***Emulsifiers***, used to aid in the formation and maintenance of the dispersion of two or more substances which would normally separate and not normally mix, such as oil and water. Milk, mayonnaise and salad dressings are typical oil in water emulsions, butter and margarine water in oil emulsions.
- *E*mulsifying salts, used to disperse protein so reducing the stringiness in cooked cheese.
- ***Firming agents***, used to make or retain firmness or crispness in fruit and vegetables and to strengthen gels.
- ***Flour improvers***, used to enhance the elastic properties and aid the development of dough. Also accelerates the effect of bleaching agents.
- ***Foaming agents***, used to provide a uniform dispersion of gas in a food.
- ***Gelling agents***, used to form a jelly so providing texture to a product.
- ***Glazing agents***, used to produce a protective coating or to impart a polish/sheen on the surface of a food such as confectionery or citrus fruit.
- ***Humectants***, used to retain moisture in foods by absorbing water from the air to prevent drying out.
- ***Modified starch***, used for various functions including adding texture, adding bulk, stabilizing and as a thickener.
- ***Packaging gases***, used to replace air in the packaging of foodstuffs susceptible to oxidation but not necessarily shown on food labels.

- ***Preservatives***, used to extend the shelf-life of products by preventing the growth of microorganisms which could otherwise cause food decay and, in some cases, food poisoning.

- ***Propellants***, a gas or volatile liquid used to expel foodstuffs from aerosols.

- ***Raising agents***, used to increase the volume of doughs and batters by promoting gas release (aeration).

- ***Releasing agents***, used to prevent foodstuffs sticking to machinery, molds, packaging etc. but not necessarily shown on food labels even though some may remain in the food.

- ***Sequestrants***, used to combine with trace metals in the environment to render them inactive.

- ***Stabilizers***, used to maintain the physical state of a food and to stabilize, retain or intensify the existing colour of a food, particularly emulsions, and therefore often used with emulsifiers.

- ***Sweeteners***, there are two different types of sweeteners:

  1. **Intense sweeteners** – these have a sweetness many times that of sugar and are therefore used at very low levels. They are used in products such as diet foods, soft drinks and table top sweeteners;

  2. **Bulk sweeteners** – these have a similar sweetness to sugar and are used at comparable levels. Unlike intense sweeteners they also provide bulk (although their main function is to provide sweetness). They are used in products such as sugar-free confectionery and foods for diabetics.

- ***Thickeners***, used to increase viscosity, modify texture and impart stability.

8.2.2 Role of Food Additives

Food additives help to enhance the consumer acceptability, help in maintaining or improving the nutritional quality, enhance stability or keeping quality by acting as antimicrobial agents with the resulting reduction in waste and prevention of chemical and biological deterioration, make food more attractive and provide sufficient aids in the food products for improving texture, colour and flavour, check spoilage by inactivating microorganisms and maintain safety of foods, facilitate preparation and help to improve palatability of the product.

It helps to enhance the shelf life of food or food products. It has been estimated that we consume about 5 kilograms of food additives as preservatives, colours, bleaches, flavours, emulsifiers and stabilizers every year in the food we eat. This not only results in extra work for our body to remove them, but frequently trigger asthma attacks; rashes; respiratory disturbances; hyperactivity in children, and in some people, an abnormal sensitivity to prescribed medications, particularly aspirin. Below are some common additives found in refined foods, and well-worth avoiding by those susceptible to their effects.

Acceptable daily intake (ADI) for various preservatives

Preservative	ADI (mg/kg body wt/day)
Acetic acid including its Na/K salts	No limit
Sodium diacetate	0-15
Benzoic acid including its Na/K salts	0-5
Formic acid	0-3
Hexamethylene tetramine	0-0.15
Para hydroxy benzoic acid esters	0-10
Lactic acid and its salts	No limit
Propionic acid and its salts	No limit
Natamycin/pimaricin	0-0.3
Na NO_3 and KNO_3	0-5
$NaNO_2$ and KNO_2	0-0.2
Sorbic acid including its Na/K/Ca salts	0-2.5
SO_2, Na_2 SO_3, $NaHSO_3$, Na/K metabisulphite	0-0.7

8.2.3 Preservatives

Preservatives are substances which are capable of inhibiting, retarding or arresting the process of fermentation, acidification or other decomposition of food or of masking any of the evidence of putrefaction but it does not include salt, sugar, vinegar, glycerol, alcohol, spices, essential oils etc. Sulphur dioxide (including sulphites) and benzoic acid (including benzoates) are among the principle preservatives used in the food processing industry. The permitted quanitity of sulphur dioxide and benzoic acid is given in the following tables.

Food additives and their usage concentrations

Food additives	Concentration (%)	Foods
Antioxidant : Butylated Hydroxy Anisole (BHA)	Not exceeding 0.02% of the total fat content and 0.01% of the finished product 0.02	*Rasogolla* and *Vadas* Whole and partially skimmed milk powder Margarine
Colours	0.02	Most foods
Flavour : Monosodium glutamate	0.05	Meat product, soup powder
Anticaking agent: Aluminum silicate	2	Table salt, onion powder, garlic powder, soup powder
Sweetening agent : Saccharin	100 ppm	Carbonated non-alcoholic drinks
Sequestrant : Ethylene Diethyle Tetra Amino Acetic Acid (EDTA)	33-800 ppm	Canned carbonated beverages, salad dressings and margarine

Classes of preservatives

CLASS I:

Common salt, sugar, dextrose, spices, vinegar or acetic acid, honey

CLASS II:

Benzoic acid and its salts, sulphur dioxide and the salts of sulphurous acid, nitrites and nitrates, sorbic acid and its salts, propionic acid and its salts, lactic acid and its salts.

Sulphur dioxide

Sulphur dioxide and its derivatives have been extensively used in foods as a food preservative. It acts both as an antioxidant and reducing agent and prevents enzymatic and non-enzymatic reactions, leading to microbial stability. The common used forms are sulphur dioxide gas and sodium, potassium and calcium salts of sulphite, bisulphite or metabisulphite. It is like a biocidal and biostatic agent and is more active against bacteria than molds and yeasts.

Sulphite or metabisulphite sprays or dip with or without added citric acid provides effective control of enzymic browning in pre-peeled and pre-sliced potatoes, carrots, mushroom and apples.

Sodium benzoate

It was the first chemical preservative permitted in foods by the FDA, and it continues in wide use today in a large number of foods. Benzoates have greatest activity at low pH. As used in acidic foods, benzoates act essentially as a mold and yeast inhibitor.

In foods such as fruit juices, benzoates may impart disagreeable tastes at the maximum level of 0.1 per cent. The taste has been described as being 'peppery 'or burning.

Permitted quantity of benzoic acid in food

Processed food	Permitted quantity of Benzoic Acid (ppm)
Non-alcoholic wines, squashes, crushes, fruit syrups, cordials, fruit juices and barley water (to be used after dilution)	600
Jams, marmalades, preserves, canned cherry, fruit jelly	200
Sweetened mineral water and sweetened ready to serve beverages	120
Brewed ginger beer	120
Pickles and chutneys	250
Tomato and other sauces	750
Danish tinned caviar	50
Tomato puree and paste	750
Syrups and sherbets	600
Fat spread	1000

Quantity of sulphur dioxide permitted in food

Processed food	Permitted quantity of SO_2 (ppm)
Sausages and sausage meat containing raw meat, cereals and condiments	450
Fruit, fruit pulp or juice (not dried) for conversion into jams or crystallized glace or cured fruit or other products	
a) cherries	2000
b) straw berries and raspberries	2000
c) other fruits	1000
Fruit juice concentrate	1000
Dried fruits	
Apricots, peaches, apples, pears and other fruit	2000
Raisins and sultanas	750
Other non-alcoholic wines. squashes, crushes, fruit syrups, cordials, fruit juices and barley water (to be used after dilution)	350
Jams, marmalade, preserves, canned cherry and fruit jelly	40
Crystallized glaced or cured fruit (including candied peel)	150
Fruit and fruit pulp not otherwise specified in the schedule	350
Plantation white sugar, cube sugar, dextrose, *gur*, jaggery or *misri*	70
Khandsari(s) and *Bura*	150
Refined sugar	40
Corn flour and similar starches	100
Corn syrup	450
Canned *rossogullas*	100
Gelatin	1000
Beer	70
Cider	200
Alcoholic wines	450
Sweetened mineral water/ready to serve beverages	70
Pickles and chutneys made from fruits or vegetables	100
Dehydrated vegetables	2000
Syrups and sherbets	350
Dried ginger	2000
Hard boiled sugar confectionery	350
Dry mixes of *rossogullas*	100

8.2.4 Acidulants

Sour or acidic taste of a food is attributed to the acidic components present in the food. Many processed foods and beverages, however, need the addition of acids to impart characteristic taste and flavour to the final food product. The intensity of sourness and ability to reduce pH vary among the organic group of acidulants in the decreasing order as follows:

Fumaric > tartaric > malic > acetic > citric > lactic > gluconic acid

Commonly used acidulants include acetic, adipic, citric, fumaric, lactic, malic, phosphoric and tartaric acids. Citric acid is the most versatile and widely used food acidulant.

Main foods in which acidulants occur or added to food

Acid	Main food
Acetic acid	Pickles, sauces, relishes, fermented vegetables and fruits, vinegar, wheat bread, cheeses and creams, apple juice, grapefruit juice.
Adipic acid	Beet juice, guava, papaya, raspberry, pork fat, dairy foods, gelatin and desserts, puddings, beverages, jams and jellies, snack foods, condiments
Citric acid	Oranges, lemons, grapefruit, black currants, gooseberries, pineapple, raspberries, strawberries
Fumaric acid	Confectionery, powdered gelatins, desserts, cheese cake, jams, and jellies
Glucono-delta-lactone	Cured meats, frankfurters, salami, sausages, dessert mixes, bakery mixes, processed cheese, fish products, spice preparation
Lactic acid	Fresh meat, yogurt, cheese, bread, pickles, sauces, relishes, fermented foods, buttermilk, wines, beer
Malic acid	Watermelon, plum, apple, cherry, peach, pear, grape, gooseberry, pineapple
Phosphoric acid	Cola beverages, jams and jellies, bread dough, cake, flour
Tartaric acid	Grapes, tamarind, pineapple, mulberries, gherkins, wines

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define food additives. What are intentional and unintentional food additives?

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2. Briefly discuss the functions of food additives.

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8.2.5 Control of Psychotropic Contamination in Food

Increasingly all types of consumers are demanding minimally processed foods that are high in quality, nutritionally superior and easy to prepare. Food processors have met this demand by developing refrigerated foods with extended shelf life. The most important bacteriological problem in processed food products today is deterioration due to contamination by psychotropic microbes, as storage at low temperature is favourable for the growth of high levels of psychrotrophic microorganisms. Psychotrophs are bacteria, yeasts and molds that grow although slowly, at refrigeration temperature (below 7°C) but grows optimally at temperatures above refrigeration, e.g. 25-30°C. Their maximum growth temperature is 30-35^{o}C. Several pathogens such as Aeromonas hydrophila, Clostridium botulinum, Listeria spp., Yersinia enterocolitica, some strains of Bacillus cereus, enteropathogenic Escherichia coli and Vibrio parahaemolyticus can grow at refrigeration temperature. These bacteria may enrich in food during cold if storage times are long enough. Some of these pathogens can cause illness when even few cells are ingested.

The control of psychrotrophs in food products should start from the very beginning of raw material procurement up to processing and storage of the finished product. The following steps are of considerable importance. Processors need to select high-quality raw materials with low levels of microorganisms, especially psychrotrophs. Fabrication of raw materials by using clean and sanitized machinery and equipments into finished products under hygienic conditions is also important. Apart from this regular check on quality of water supply and proper chlorination of water used in the food industry should be done. Appropriate use of salt and other ingredients which reduces the a_w to 0.98 or below will lengthen the lag phase of most bacteria and will further reduce the rate of any subsequent growth. Most recent studies have shifted to the use of lactic acid bacteria that produces bactericidal chemicals called bacteriocins to slow or inhibit the growth of psychrotrophic organisms. By lactic acid bacteria a wide variety of food borne pathogens are either inhibited or killed, and many spoilage organisms are affected in similar ways, especially Gram-negative psychrotophs.

Thus the effective control of microbial contaminants must begin on the farm and be followed through to the retail store. Clean equipment and packages, use of approved food additives and chemical preservatives of Generally Recognized As Safe (GRAS) status in proper concentration, limited time of storage, low holding temperatures for raw materials and the finished product, effective laboratory control and attention to good manufacturing practices which will slow the outgrow of psychrotrophs will help the food plant to produce with good yield, good flavour, long shelf –life and high sales appeal.

8.3 GENERAL CONSIDERATIONS IN THE SELECTION OF CHEMICAL FOOD PRESERVATIVES

Antimicrobial preservatives added to foods can be grouped as follows:

1. *Those added preservatives not defined as such by law:* natural organic acids (lactic, malic, citric etc.) and their salts, vinegar, sodium chloride, sugars, spices and their oils, woodsmoke, carbon dioxide and nitrogen
2. *Substances generally recognized as safe (GRAS) for addition to foods:* propionic acid and sodium and calcium propionate, caprylic acid, sorbic acid and its salts, sulphur dioxide, sodium nitrite
3. *Chemicals considered to be food additives*, which would include all that are not included in the first two categories
4. *Chemicals proved safe and approved by the Food and Drug Administration*

8.3.1 Desirable Properties of Food Preservatives

There are seven requirements for food preservatives:

- No toxicity problems.
- Microbiocidal rather than microbiostatic properties.
- Must be stable in foods (especially if only microbiostatic).
- The spectrum of activity should correspond to the spectrum of micro-organisms likely to appear in the food.
- Must not stimulate the development of resistant strains of microorganisms.
- Chemicals used therapeutically are not recommended as food additives.
- An assay procedure should be available.

Categories of Antimicrobial Food Additives Added to the Food:

Following chemicals and biochemicals are used in food preservation:

- Naturally present or formed in the food, chemicals added to the food, bacteriocins e.g. lactoperoxidase enzyme, lysozyme, lactoferrin, nisin etc.

- Chemicals with antimicrobial properties of salts of organic acids, like citric, benzoic, propionic and ascorbic. Chemical preservatives (sulphur dioxide and sulphites, parabens etc.), nitrites and nitrates.

- Chemicals with multifunctional properties added to the food, one property being antimicrobial e.g. spices and essential oils, salt, sugar, antioxidants, vinegar etc.

8.3.2 Mode of Action of Food Additives

- Alteration of cell wall permeability.
- Alteration of colloidal nature of protoplasm.
- Damage of the cell wall.
- Damage of proteins.
- Inhibition of enzyme activity.
- Disruption of cytoplasmic membrane.
- Bacteriostatic or bactericidal action (toxicity of the antimicrobial agent towards microorganisms).
- Interference with synthetic processes.

8.3.3 Factors Affecting the Antimicrobial Activity of Food Additives

Many factors must be considered for the selection of a specific antimicrobial food additive for a specific food. These factors are as follows:

- Physical and chemical properties of the antimicrobial agents (such as water solubility, hydrophobic lipophyllic balance, boiling point, ability to ionize and potential interaction with food constituents). The activity of the antimicrobial is reduced as a result of reaction with lipids, proteins or carbohydrates.

- Composition of food, its pH/ acidity and nutritional value.

- Type of preservation system other than chemicals used in the food.

- Characteristics and number of microorganisms.

- Initial contamination by microbes prior to preservation/processing.

- Type and concentration of chemical used.

- Time and temperature of food storage.

- Cost and toxicity of the antimicrobial.

8.3.4 Precautions to be taken for Using Food Additives

- Food additives must be thoroughly tested before use. Foods containing physical hazards such as stones, seeds, glass fragments or metal pieces must be thoroughly checked.

- FDA approved food additives should be used. Improper use of some of them may prove to be harmful to human health.

- Use of additives should not be permitted if:
  - They fail to serve the interest of consumers.
  - They are used to mark the effect of faulty processing and handling techniques.
  - They are used to deceive the consumers.
  - Their use results in a significant reduction in the nutritive value of the foods.
  - Additives should be used in a controlled way so as to maximize benefits and prevent abuses.

Status of some additives and acceptable dietary intake (ADI)

Material	**Status**
Amaranth (red ozo dye)	Carcinogenic, but still WHO/FAO-prescribed an ADI* for Amaranth
Saccharin	Bladder cancer. However, still permitted in soft drinks to the extent of 100ppm. WHO/FAO-prescribed ADI from 2.5-5.0 mg/kg of body weight.
Cyclamate	Bladder cancer. WHO/FAO-prescribed ADI of 4 mg/kg of body weight for cyclamate.
Brominated vegetable oil	Banned in India and UK
Hydrogen peroxide	Used for extending shelf-life of milk, is repeatedly turned down on grounds that it would have undesirable consequences on milk collection practices.
Gallate, Phenols	Permitted in most countries, but in India there use required specific permission which is not granted.
Nitrates and nitrites	Give rise to nitrosamine which are carcinogenic but still used in our country within the permissible limit.
Sulphites	Banned in USA

*ADI-Acceptable Daily Intake (mg/kg body weight/day)

8.3.5 Adverse Effects of Using Food Additives

Although these additives are regarded as GRAS (generally recognized as safe), their increased used may also lead to various health problems viz. acidity, dyspepsia, digestive disorders etc.

Food additive name	Often used in	Common reactions
Tartrazine (colour)	drinks, cakes, snacks, ice-cream, confectionery	asthma; hyperactivity; aspirin sensitivity
Sunset yellow (colour)	drinks, packet soups, dessert, biscuits, confectionery, ice-cream	hyperactivity; allergies; aspirin sensitivity
Cochineal (colour)	cakes, confectionery, ice-cream	hyperactivity
Azorubine (colour)	packet soups, sauces, jams, desserts (jellies)	asthma; hyperactivity; asprin sensitivity
Indigotine (colour)	tablets, capsules, ice cream, biscuits	nausea; skin rashes; allergies; high blood pressure
Brilliant blue (colour)	tinned peas, bacon-flavored snacks	hyperactivity
Caramel (colour)	drinks, sauces, soups, cakes, pickles, vinegar	hyperactivity
Benzoic acid (preservative)	confectionery, cheeses,	asthma; hyperactivity;
Sulphur dioxide (preservative)	beer, wine, soft drinks, dried fruit, cordials	asthma; hyperactivity
Sodium bisulphite (preservative)	wine, beer, soft drinks, juices, cordials	asthma; destroys vitamin B1; hyperactivity
Sodium nitrite (preservative)	cured meats, some cheeses	hyperactivity; adverse reactions in children; potentially carcinogenic
Propyl gallate (antioxidant)	oils, margarine, salad dressings	gastric and skin irritant
Tert-butyl hydroquinone (antioxidant)	fats, oils, margarine, packet chips	nausea; delirium
Butylated hydroxyanisole (antioxidant)	fried snacks, soft drinks, edible oils, margarine, chewing gum	hyperactivity; asthma; adverse reactions; allergies; increases cholesterol levels
Carageenan (thickener) (emulsifier)	ice-cream, jellies, cake decorations, cheese, salad dressings	allergies; intolerances
Mannitol (emulsifier)	icecream, confectionery, low calorie foods	allergies; diarrhoea, nausea
Monosodium glutamate (MSG) (flavour enhancer)	prepacked meals, snacks, Chinese cooking	hyperactivity; asthma; adverse reactions; allergies; aspirin sensitivity

Disodium 5' ribonucleotide (flavour enhancer)	flavoured crisps, instant noodles, party pies	skin rashes; not easily broken down by body
Aspartame (sweetener)	diet drinks, diabetic confectionery, ice cream	allergies; headaches; nervous disorders

8.4 DEVELOPED AND ADDED PRESERVATIVES

Developed preservatives include those synthesized naturally, by various microorganisms during fermentation and growth and metabolism.

8.4.1 Acids Produced during Fermentation

Food fermentations may serve either or both of two purposes: (1) to produce new and desired flavours and physical characteristics and hence a different food product and (2) to help preserve the food. The preservatives produced in foods by microbial action are the most part acids (chiefly lactic) and alcohol. The preservative effect of these substances nearly always is supplemented by one or more additional preservative agents, such as low temperature, heat, anaerobic conditions, sodium chloride, sugar or added acid.

Developed acidity plays an important part in the preservation of sauerkraut, pickles, green olives, fermented milk, cheese and certain sausages and in various fermented foods of plant origin. Development of full amount of acidity from the sugar available may be permitted in the pickle and green olive fermentations, or the fermentation may be stopped by chilling or canning before the maximum acidity is attained in other fermentations. The approximate acidity developed in some of these products, expressed as lactic acid, is sauerkraut, 1.7 per cent: dill pickles and green olives, 0.9 per cent and fermented milks, 0.6 to 0.85 per cent.

8.4.2 Alcohol

The alcohol content of beer, ale, fermented fruit juices and distilled liquors has a preservative effect but was not produced primarily for that purpose.

8.4.3 Bacteriocins

Many natural products have been found to have efficient preservative effect and their application in food is catching up fast due to the increased awareness about their nutritional and health benefits. These are termed as bio-preservatives as they act on harmful spoilage and pathogenic microbes and prevent their growth in foods.

Bacteriocins constitute an important segment of these biopreservatives. Technically speaking, the bacteriocins are proteinaceous antimicrobial compounds that kill or inhibit closely related bacteria and also are capable of exhibiting a wide inhibitory spectrum against spoilage and pathogenic bacteria. Various microorganisms such as the lactic acid bacteria (comprising species of *Lactobacillus, Lactococcus, Leuconostoc* and *Pediococcus*) and species of *Corynebacterium, Propionibacterium, Enterococcus, Bacillus* and *Escherichia* have been reported to produce bacteriocins or bacteriocin-like inhibitory substances. Lactic acid bacteria have been shown to produce sufficient quantities of bacteriocins in various cultured and fermented food preparations (*dahi*, yogurt, cheese etc.) to prevent the growth of harmful bacteria. Alternatively the purified bacteriocin preparation can also be added directly to the food. So far, researchers have extensively tried out only two bacteriocins, namely nisin and pediocin as biopreservatives in various food systems of which nisin is the only bacteriocin that has been approved as a GRAS food additives.

Nisin is a well known and most widely used bacteriocin produced by *Lactococcus lactis* subsp. *lactis* (formerly *Streptococcus lactis*). It has been used in processed cheese, pasteurized milks, flavored milk and various other dairy products, in addition to canned foods and alcoholic beverages. The recommended doses of nisin used varies from 100-150 IU/g depending on the type of food. Nisin has sporostatic activity. This results in significant energy savings in canning processes by way of low heat application. So it is useful for the non-thermal preservation of foods. Nisin also has a great potential for use in brewing industry. It also finds application in low pH foods. In many European countries nisin has affirmed GRAS status in 1998 by Food and Drug Administration (FDA) for use as an antimicrobial agent.

Besides nisin, several other bacteriocins produced by lactic acid bacteria include pediocin PA-I and pediocin AcH produced by Pediococcus *acidilacti*, sakacin A from *Lactobacillus sake*, plantaricin from *Lactobacillus plantarum*, acidophilicin LA-I from *Lactobacillus acidophilus* and helveticin J produced by *Lactobacillus helveticus* and so on. The Pediococci which are used as starter cultures in certain vegetable and meat fermentations have also been the subject of recent investigation with regard to their bacteriocin-producing ability.

Advantages of using bacteriocins: The bacteriocins offer several advantages over the preservatives that are presently being used in several foods. They do not have any ill effect on the health of the consumer so they are safe to use and the inhibitory effect of bacteriocins on the growth of microorganisms exhibits the potential to inactivate microorganisms in foods.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define bacteriocins. Give a few examples and possible uses.

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2. What are the desirable characteristics of food additives?

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3. List down the mode of action of food additives.

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8.5 LET US SUM UP

Chemical additives that control microorganisms are not only a technological and functional tool in hands of food technologists but also aid in restoring the nutrients lost through processing. The availability of chemical/food additives has allowed the production of numerous out-of-season foods and a variety of new food products. Additives have increased the development of convenience foods, snack foods, low-calorie and health promoting (functional) foods, exotic foods and a variety of food substitutes. The present day consumer demands high quality, convenient and minimally processed foods. Some products can be formulated with ingredients such as organic acids, chemical preservatives, nitrite, bacteriocins, high concentrations of salt, carbon dioxide etc. that are barriers to microbial growth and can also inhibit there growth due to their antibacterial and antifungal properties. The role of chemical additives thus, becomes all the more important, hence to be selected judiciously, keeping in view their toxicological and biochemical role in food, before they are recommended and they have become an integral part of food industry for day to day life for the production of various processed products. They help to assure a food supply with the safety, variety, appeal, wholesomeness and affordability we have become accustomed to.

8.6 KEY WORDS

Food Additive	:	Food additive is defined as a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging. The term does not include chance contaminants.
Bacteriocin	:	Proteinaceous antimicrobial compounds that kill or inhibit closely related bacteria and also are capable of exhibiting a wide inhibitory spectrum against spoilage and pathogenic bacteria.
Nisin	:	Widely used bacteriocin produced by *Lactococcus lactis* subsp. *lactis* (formerly *Streptococcus lactis*).
GRAS	:	Substances generally recognized as safe
ADI	:	The Acceptable Daily Intake (ADI) is defined as an estimate of the amount of a food additive, expressed on a bodyweight basis that can be

ingested on a daily basis in the diet over a lifetime without appreciable risk to health. "Without appreciable risk" means the practical, in view of the actual level of knowledge, certainty that no harm will result, even after a lifetime of exposure to the chemical additive concerned. The ADI is usually given as a range of 0-x milligrams per kilogram of bodyweight per day.

8.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. - Food additive is a substance or mixture of substances other than the basic foodstuff, which is present in food as a result of any aspect of production, processing, storage and packaging.
   - Intentional food additives are added deliberately to food and could be nutritive, freshness maintaining, sensory and processing aids; preservatives, antioxidants, emulsifiers, stabilizers, maturing agents, colours, special sweeteners, nutrient supplements, flavouring compounds and natural flavouring materials.
   - Unintentional food additives are chance contaminants which may get incorporated into food during any step of processing and are not desirable.
2. Food additives help to:
   - Enhance consumer acceptability.
   - Help improve or maintain the nutritional quality.
   - Enhance stability and prevent deterioration.
   - Make food more attractive and palatable.
   - Maintain the safety of foods.

Check Your Progress Exercise 2

1. - Bacteriocins are proteinaceous antimicrobial compounds produced by bacteria, that kill or inhibit closely related spoilage and pathogenic bacteria eg: Nisin, Pediocin, Acidophillin etc.
   - They are used in processed cheese, pasteurized milks, flavored milks and various other dairy products, canned foods and alcoholic drinks, brewing industry etc.
2. Food additives should be non-toxic, economical, must be stable in foods, should be microbiocidal rather than microbiostatic, should have broad antimicrobial spectrum, must prevent growth of resistant strains and an assay procedure should be available to detect them.

3. Action of food additives is by:
   - Altering cell wall permeability of bacteria.
   - Altering its protoplasm.
   - Damaging proteins and cell wall.
   - Inhibition of enzyme activity of cell.
   - Disruption of cell membrane and interfering with cell synthesis processes.

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UNIT 9 FOOD BORN DISEASES

Structure

9.0 OBJECTIVES

After reading this unit, you will be able to:

- know the food borne diseases;
- learn to differentiate between food borne intoxications and food borne infections;
- explain that the food borne diseases may be caused due to microorganisms, both bacterial and non bacterial or chemicals;
- explain why investigation of food borne disease outbreak is necessary; and
- describe how the investigation of food borne disease outbreak is carried out.

9.1 INTRODUCTION

Food borne disease (FBD) is caused by consuming contaminated foods or beverages. In addition poisonous chemicals or other harmful substitutes can cause food borne diseases if they are present in food. More than 250 different food borne diseases have been described. A classification of food borne diseases is given in Figure 9.1. Food borne diseases may be intestinal diseases but can be other type as well.

9.2 TYPES OF FOOD BORN DISEASES

With regard to their epidemiology, they can be divided into two major categories (Figure 9.2):

i) **Food borne Intoxication:** Examples include botulism or staphylococcal food poisoning, the causative microorganism produces an exotoxin in food: when a person consumes the food, the toxin is ingested and gives rise to disease.

ii) **Food borne Infections:** the causative organisms are ingested: these subsequently grow within the body and cause damage.

Both infections and intoxications often cause diarrhoea. Severe diarrhoea accompanied by blood or mucus is called dysentery. Both types of digestive system diseases are also frequently accompanied by abdominal cramps, nausea and vomiting. Diarrhoea and vomiting are both defensive mechanisms designed to rid the body of harmful material.

The general term gastroenteritis is applied to disease causing inflammation of the stomach and intestinal mucosa.

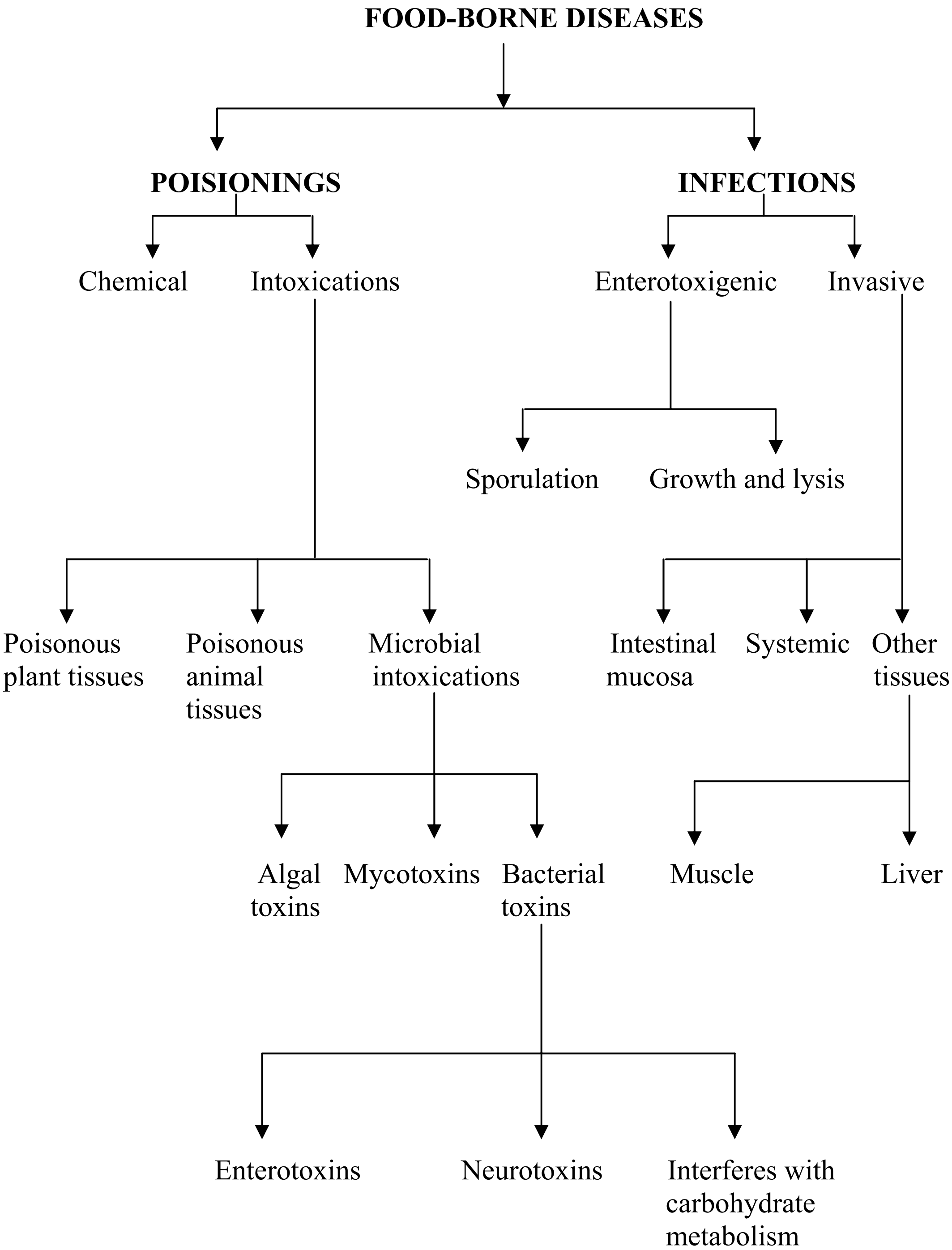

Figure 9.1: Classification of food borne diseases

FOOD-BORNE DISEASES: BACTERIAL

Intoxications

1. Staphylococcal intoxication (staphyloccocal enterotoxicosis): an enterotoxin produced by *Staphylococcus aureus*
2. Botulism: a neurotoxin produced by *Clostridium botulinum*

Infections

1. Salmonellois: enterotoxin and cytotoxin of *Salmonella* spp.
2. *Clostridium perfrigens* illness: an enterotoxin released during sporulation of *Clostridium perfringens* type A in the intestinal tract
3. *Bacillus cereus* gastroenteritis: an exo-enterotoxin released during lysis of *Bacillus cereus* in the intestinal tract
4. *Enteropathogenic Escherichia coli* infection: Several serotypes of *E. coli,* some invasive and some enterotoxigenic
5. *Others:* Yersiniosis, Shigellosis *Vibrio parahaemolyticus*

Figure 9.2: Bacteria responsible for food borne intoxications and infections

9.3 HUMAN DISEASES

Microorganisms that produce infectious diseases in human are categorized as pathogens, because they have the ability to injure body tissues and/or alter body functions.

In general, pathogenic microorganisms express their disease-producing properties through two kinds of mechanisms: (1) invasion of tissues (invasive microorganisms) and (2) production of toxins (toxigenic microorganisms).

Invasive pathogens have the ability to produce and excrete one or more kinds of extracellular enzymes resulting in injury to host tissues. Toxigenic microorganisms produce toxins of two types:

- Exotoxins – produced within certain kinds of bacteria and excreted into their surrounding environment. They are proteins in chemical composition and are relatively specific in terms of damage to the host.
- Endotoxins – are complex polysaccharides cell wall components of certain kind of bacteria. They are not released until the cell disintegrates. They are relatively heat stable, less specific in their actions and less potent than exotoxins.

The severity and distribution of any infectious disease are influenced by the manner in which the agent, the host and factors within the environment interact.

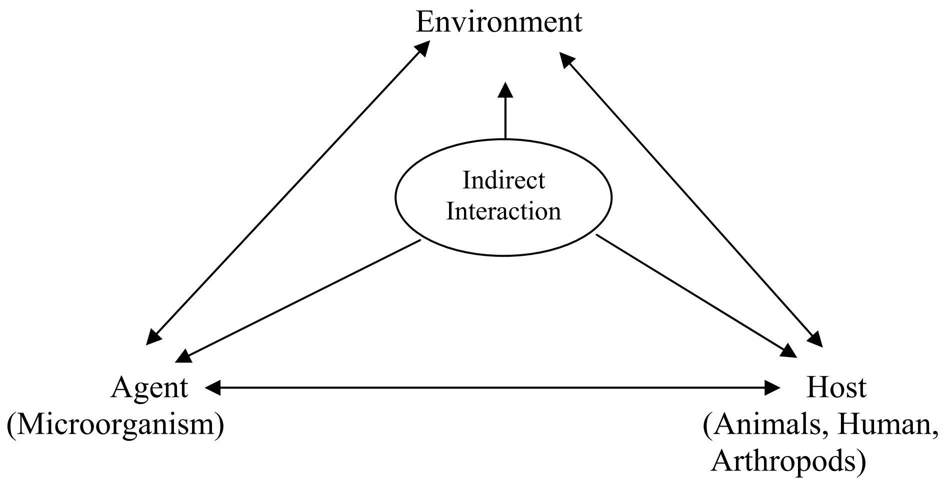

Figure 9.3: Generalized version of the triangle of causation for any kind of communicable disease

The main causes of reported food borne diseases are due to foods being mishandled. Foods that are implicated are usually "potentially hazardous" which are capable of supportive growth of disease-causing microorganisms. The various factors leading to FBD are listed in Table.

Table 9.1: Factors leading to reported food borne diseases (Ranked by % number of outbreaks)

40%	Improper cooling of foods
21%	Time lapse between preparing to serving
20%	Infected persons touching foods
16%	Inadequate cooling
16%	Improper hot storage
12%	Inadequate reheating
11%	Contaminated raw food
7%	Cross-contamination
7%	Improper cleaning
4%	Use of leftovers

9.4 CHEMICAL CONTAMINANTS OF FOOD

Poisoning by consumption of chemicals is rather uncommon and usually is characterized by appearance of the symptoms within a short period of time after the poisonous food is eaten. Various chemical contaminants include:

i) Fumigants are used to sterilize food under conditions in which steam heating is impractical. Ethylene oxide is a commonly used fumigant, which reacts with food constituents and destroys essential nutrients. It reacts with inorganic chloride to form ethylene chloro hydrine, which is toxic.

ii) Various solvents are used for the extraction of oil from oilseeds. But solvents like trichloro ethylene react with the foodstuff being processed with the formation of toxic products.

iii) Smoking of meat and fish for preservation and flavouring is an old practice. This processing contaminates the food with polycyclic hydrocarbons such as benzopyrene, many of which are carcinogenic.

iv) Metals are one of the many unintentional contaminants of food. When present beyond small quantities they are toxic. They find their way into food through air, water, soil, industrial pollution and other routes. Antimony, arsenic, cadmium, chlorinated hydrocarbons, copper, cyanide, fluoride, lead, selenium, mercury and zinc in foods have been blamed for food poisoning. Poisonous chemicals may enter foods from utensils e.g. from cheap enamelled utensils which contain antimony. Lead and arsenic residues from fruit sprays maybe on the surface of fruits but usually in harmless amounts, especially after washing. Symptoms of lead poisoning include weakness, dental caries, nausea, pains and paralysis. A major source of tin contamination is tin plate, which is used for containers of all types of processed foods. Canned foods if acidic and foods stored in tins after opening, change in colour, or develop a metallic flavour that is unacceptable. Insecticides, pesticides, growth regulators, fungicides and growth stimulators are essential in modern agriculture for the production of adequate quantities of sound food. They include insecticides like lead arsenate, organophosphate compounds (malathion), dinitro compounds. Toxicity levels for human vary.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are food borne diseases?

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2. Differentiate between exotoxins and endotoxins.

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3. List the various chemical contaminants in food.

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Table 9.2: Toxicity of some metals in different foods

Metal	Type of Food	Toxic Effect
Arsenic	Fruits sprayed with lead arsenate	Dizziness, chills, cramps, paralysis leading to death
Barium	Foods contaminated with rat poison (barium carbonate)	Violet peristalsis, muscular twitching and convulsions
Cadmium	Fruit juice, soft drinks in contact with cadmium plated vessels	Excessive salivation and kidney damage, prostrate cancer, multiple fractures
Cobalt	Water, beer	Cardiac failure
Copper	Acid foods in contact with tarnished copper ware and brass utensils	Vomiting, diarrhea, abdominal pain
Lead	Processed foods	Paralysis, brain damage
Mercury	Mercury fungicide treated seed grains or mercury contaminated fish	Paralysis, brain damage and blindness
Tin	Canned foods	Colic, vomiting. Photophobia
Zinc	Foods stored in galvanized iron ware	Dizziness, vomiting

Table 9.3: Toxicity in food due to various pesticides and chemicals

Name of Pesticide	Type of Food	Toxic Effect
Pesticides	All type of raw, cooked, processed, canned foods	Acute or chronic poisoning causing damage to liver, kidney, brain, nerves leading to death
Diethylstil bestrol	Meat of still bestrol fed animals	Teratogenesis, carcinogenesis
Antibiotics	Meat of animals fed antibiotics	Drug resistance, hardening of arteries, heart diseases

Table 9.4: Permissible limits of some metals in foods

Name of metal	Foodstuff	PPM
Arsenic	1. Milk	0.10
	2. Beverages	0.50
	3. Soft Drinks	0.50
	4. Ice creams and frozen confections	0.50
	5. Dehydrated onions	2.0
	6. Dried spices and herbs	5.0
Copper	1. Beverages, soft drinks	7.0
	2. Tomato ketchup	50.0
	3. Cocoa powder	70.0
	4. Tomato puree, paste, juice powder	100.0
	5. Sugar confectionary	5.0
Lead	1. Beverages and soft drinks	0.50
	2. Fruits and vegetable juices	1.0
	3. Ice cream, frozen confections, canned fish, meat, dehydrated vegetables	1.0
Tin	1. Processed and canned foods	5.0
	2. Hard boiled sugar confectionary	5.0
Zinc	1. Beverages	5.0
	2. Fruit products	50.0
	3. Hard boiled sugar confectionary	5.0

9.5 NON-BACTERIAL MICROBIOLOGICAL CONTAMINATION OF FOOD

Microbiological contamination of food may include food borne illness due to bacteria or non bacterial sources such as mycotoxins, viruses, rickettsias, parasitic worms or protozoa or from the consumption of food contaminated with toxic substances. The food borne infections caused by bacteria will be dealt with in Unit 3 in detail.

9.5.1 Viruses

Much less is known about the incidence of viruses in foods than about bacteria and fungi because they do not grow in culture media as do bacteria and fungi, they do not replicate in foods thus found in low numbers. It is noted that virtually any food can serve as a vehicle for virus transmission. The most common food source of gastroenteritis causing virus is shellfish.

Hepatitis A virus

There are more documented outbreaks of hepatitis A traced to foods than any other viral infection. The virus causes hepatitis (jaundice) and leads to inflammation of liver. The incubation period for infectious hepatitis ranges from 15 to 45 days and lifetime immunity usually occurs after an attack. The fecal-oral route is the mode of transmission, and raw or partially cooked shellfish from polluted waters is the most common vehicle food. Shellfish are able to concentrate the numbers of bacteria or viruses during their normal feeding, which is to filter and remove particles from the water. The infectious hepatitis virus has been shown to be stable during refrigerated storage of shellfish. In addition to shellfish, raw milk, potato salad, sandwiches and cold meat cuts are also probable sources of the virus. Symptoms of jaundice include loss of appetite, yellowing of eyes, nails and skin (due to presence of bile pigments) and gastrointestinal disorder. Proper cooking, hygiene, sanitation and personnel cleanliness help to prevent virus attack.

Polio Virus

There are a large number of reported food-borne outbreaks of polio in India. It is most common in children up to 5 years. Milk is the most probable food there causes spread of polio virus. The virus reproduces in the intestinal tract, from there it invades the motor cells of the central nervous system. Initial symptoms are gastrointestinal, headache, muscle pain and paralysis. The paralytic symptoms range from sub clinical to fatal. Preventive measures include immunization of children, proper processing (pasteurization) of milk, hygienic conditions and use of potable water.

Norwalk Virus and Norwalk-like Viruses

These viruses, also known as small round structured viruses or caliciviruses, are an important cause of gastrointestinal illness throughout the United States. Members of this category of viruses are typically named for the location in which they were first identified, for example, Hawaii, Snow Mountain, Montgomery County and Oklahoma. The Norwalk virus is the prototype for this group of viruses – there are at least 11 other related viruses – hence the name “Norwalk-like virus.”

Symptoms: The signs and symptoms of Norwalk-like viruses include nausea, vomiting, diarrhea, abdominal pain, muscle aches, headache, tiredness and low-grade fever. Symptoms typically last 24 hours to 48 hours and subside on their own. There are no known long-term effects after recovery from this infection.

Transmission of viruses: Humans are the only source for these viruses. These viruses do not multiply outside the human body. The viruses are present in the feces of infected persons and can be transmitted to others when hands are not thoroughly washed after having a bowel movement.

9.5.2 Rickettsias

Rickettsias maybe considered as degenerative bacteria since they represent a form of life closely resembling bacteria except that they cannot be cultivated outside of living cells. Like the viruses they are obligate parasites. Many of the major human rickettsial diseases are by bites from fleas, lice or ticks. Examples of human rickettsial diseases include epidemic typhus, rickettsial pox, Rocky mountain spotted fever and Q fever. Cows infected with rickettsia of Q fever, *Coxiella brunettii* excrete contaminated milk which result in human infections. Hence milk is pasteurized at a minimum temperature of 62.8ºC for 30 minutes to ensure its destruction.

9.5.3 Food Borne Parasites

Trichinosis

Trichinella spiralis causes trichinosis, which results from the consumption of raw or incompletely cooked pork containing the encysted larvae.

Symptoms: One or two days after ingestion of heavily encysted meat, trichinae penetrate the intestinal mucosa, producing nausea, abdominal pain, diarrhea and sometimes vomiting. The symptoms may persist for several days. The larvae then attack the skeletal muscles, muscle pain (paralysis) is the universal symptom accompanied in difficulty in breathing, chewing and swallowing. After six months of initial infection, pain, swelling and fever occur.

Prevention and control: Chief method for prevention of trichinosis is the treatment of pork (or other meat) to ensure the destruction of any trichinae that maybe present by cooking of pork till at least 58.3ºC, quick freezing or storage at -15ºC or lower for not less than 20 days, irradiating or processing of sausage and similar meat products properly by salting, drying, smoking and refrigeration. Also trichinosis can be controlled by avoiding feeding of infected meat scraps to swine and by preventing the consumption of infested tissue by other animals.

Amoebiasis

Entamoeba histolytica is a single celled parasitic animal – a protozoa, that infects predominantly humans and other primates and causes amoebiasis. Diverse mammals such as dogs and cats can become infected but usually do not shed cysts (the environmental survival form of the organism) with their feces, thus do not contribute significantly to transmission. The active (trophozoite) stage exists only in the host and in fresh feces; cysts survive outside the host in water and soil and on foods, especially under moist conditions on the latter. When swallowed they cause infections by excysting (to the trophozoite stage) in the digestive tract (amoebiasis).

Symptoms: Infections that sometimes last for years may be accompanied by 1) no symptoms, 2) vague gastrointestinal distress, 3) dysentery (with blood and mucus). Most infections occur in the digestive tract but other tissues may be invaded. Complications include 4) ulcerative and abscess pain and, rarely, 5) intestinal blockage. Onset time is highly variable. It is theorized that the absence of symptoms or their intensity varies with such factors as 1) strain of amoeba, 2) immune health of the host, and 3) associated bacteria and, perhaps, viruses. The amoeba's enzymes help it to penetrate and digest human tissues; it secretes toxic substances.

Diagnosis: The ingestion of one viable cyst can cause an infection. Human cases are diagnosed by finding cysts shed with the stool; various flotation or sedimentation procedures have been developed to recover the cysts from fecal matter; stains (including fluorescent antibody) help to visualize the isolated cysts for microscopic examination. Since cysts are not shed constantly, a minimum of 3 stools should be examined. In heavy infections, the motile form (the trophozoite) can be seen in fresh feces. Serological tests exist for long-term infections. It is important to distinguish the *E. histolytica* cyst from the cysts of nonpathogenic intestinal protozoa by its appearance.

Transmission: Amebiasis is transmitted by fecal contamination of drinking water and foods, but also by direct contact with dirty hands or objects as well as by sexual contact.

Giardiasis

Giardia lamblia (intestinalis) is a single celled animal, i.e., a protozoa, that moves with the aid of five flagella. Organisms that appear identical to those that cause human illness have been isolated from domestic animals (dogs and cats) and wild animals (beavers and bears). A related but morphologically distinct organism infects rodents, although rodents may be infected with human isolates in the laboratory. Human giardiasis may involve diarrhea within 1 week of ingestion of the cyst, which is the environmental survival form and infective stage of the organism.

Symptoms: Normally illness lasts for 1 to 2 weeks, but there are cases of chronic infections lasting months to years. Chronic cases, both those with defined immune deficiencies and those without, are difficult to treat. The disease mechanism is unknown, with some investigators reporting that the organism produces a toxin while others are unable to confirm its existence. The organism has been demonstrated inside host cells in the duodenum, but most investigators think this is such an infrequent occurrence that it is not responsible for disease symptoms. Mechanical obstruction of the absorptive surface of the intestine has been proposed as a possible pathogenic mechanism, as has a synergistic relationship with some of the intestinal flora.

Diagnosis: *Giardia lamblia* is frequently diagnosed by visualizing the organism, either the trophozoite (active reproducing form) or the cyst (the resting stage that is resistant to adverse environmental conditions) in stained preparations or unstained wet mounts with the aid of a microscope. A commercial fluorescent antibody kit is available to stain the organism. Organisms may be concentrated by sedimentation or flotation; however, these procedures reduce the number of recognizable organisms in the sample.

Associated foods: Giardiasis is most frequently associated with the consumption of contaminated water. Outbreaks have been traced to food contamination by infected or infested food handlers, and the possibility of infections from contaminated vegetables that are eaten raw cannot be excluded. Cool moist conditions favor the survival of the organism.

Prevalence: Giardiasis is more prevalent in children than in adults, possibly because many individuals seem to have a lasting immunity after infection. This organism is implicated in 25% of the cases of gastrointestinal disease and may be present asymptomatically. This disease afflicts many homosexual men, both HIV-positive and HIV-negative individuals. This is presumed to be due to sexual transmission. The disease is also common in child day care centers, especially those in which diapering is done.

Ascariasis

Humans worldwide are infected with *Ascaris lumbricoides* and *Trichuris trichiura*; the eggs of these roundworms (nematode) which are "sticky" and may be carried to the mouth by hands, other body parts, fomites (inanimate objects), or foods. Ascariasis and trichuriasis are the scientific names of these infections. Ascariasis is also known commonly as the "large roundworm" infection and trichuriasis as "whip worm" infection.

Diagnosis: Infection with one or a few Ascaris sp. may be unapparent unless noticed when passed in the feces, or, on occasion, crawling up into the throat and trying to exit through the mouth or nose. Infection with numerous worms may result in a pneumonitis in the lungs, where the larvae break out of the pulmonary capillaries into the air sacs, ascend into the throat and descend to the small intestine again where they grow, becoming as large as 31 × 4 cm. Vague digestive tract discomfort sometimes accompanies the intestinal infection, but in small children with more than a few worms there may be intestinal blockage because of the worms' large size. Not all larval or adult worms stay on the path that is optimal for their development; those that wander may locate in diverse sites throughout the body and cause complications. Both infections are diagnosed by finding the typical eggs in the patient's feces; on occasion the larval or adult worms are found in the feces or, especially for *Ascaris* sp., in the throat, mouth, or nose.

Associated foods: The eggs of these worms are found in insufficiently treated sewage-fertilizer and in soils where they embryonate (i.e., larvae develop in fertilized eggs). The eggs may contaminate crops grown in soil or fertilized with sewage that has received nonlethal treatment; humans are infected when such produce is consumed raw. Infected food handlers may contaminate a wide variety of foods.

Prevention: Both infections may self-cure after the larvae have matured into adults or may require anthelmintic treatment. In severe cases, surgical removal may be necessary. Allergic symptoms (especially but not exclusively of the asthmatic sort) are common in long-lasting infections or upon reinfection in ascariasis.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the non-bacterial food borne disease causing agents?

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2. What is the causative organism for jaundice and how is it transmitted?

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3. List the food-borne parasites. What are the symptoms of the disease cause by them?

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9.6 INVESTIGATION OF FOOD BORNE DISEASE OUTBREAK

Analysis of an outbreak involves field analysis as well as laboratory analysis and is undertaken by Ministry of Health. From public health point of view the objectives of the investigation of outbreak are:

1. *Prevention and control*

   Identification of contaminated foods

2. *Knowledge of disease causation*

   Observe the track record of various illnesses-causing agents

3. *Administration guidance*

   Assessment of trends to justify regulations, decisions/actions

This requires the location and the identification of the causative agent, establishing of the means of transmission, demonstration of opportunity for growth of the pathogen.

Personnel Involved in Investigation

The team to investigate an outbreak of food borne disease consists of a person in charge, a field group and a laboratory group. The field group interviews persons, both ill and healthy, who consumed the suspected foods, physicians and nurses who are treating the victims, and personnel at the place of exposure to the disease; collects samples of suspected foods and transits them to the laboratory, collects specimens from patients or food handlers when such sample is indicated; inspects the premises where the foods were stored, prepared and served; fills out appropriate reports on these activities, and makes it available for laboratory staff. The laboratory group makes microbiological and chemical tests as indicated by reports of the field group and the nature of the suspected food and records its findings on appropriate report blanks. The person in-charge or a qualified epidemiologist then can interpret the data from all sources to determine the cause and source of disease outbreak.

Steps of Investigation

Field Analysis

a) Gathering information

The field group inspects the place or places where the suspected meal, meals or beverages were prepared and consumed and then record the results in appropriate forms. Information sought includes the menu for meals, source and method of preparation of each item on the menu, methods of storage of perishable foods, health of employees serving or preparing foods and their health history. The information obtained is recorded on a form entitled "Case History Questionnaire" as given.

Performa

Name of Person affected	Age	Time of First Symptom	Foods Consumed

The Performa indicate the most likely age group affected and the type of food being consumed by them. Also we get an idea of the type of food through which the infection could have probably been caused.

b) Sample collection

Samples of left over food and /or beverage served at suspected meal are aseptically collected by means of sterile sampling devices in sterile containers, labelled and transited to laboratory under refrigerated conditions.

c) Collection of specimens from human sources

Specimens maybe obtained from patients with food illnesses or from food handlers to ascertain the ultimate source of the pathogen that entered the food. Culture from nose, throat or skin lesions, fecal or blood samples may be done.

Laboratory Analysis

The sample received from the field are analyzed microbiologically and sometimes for chemical contamination also. The report is then sent to the in-charge, the epidemiologist (who is expert in dealing with epidemics).

Performa for Laboratory Report

Etiological Agent (Causative Agent of Spoilage)	Clinical Symptoms (of affected people)	Laboratory Investigation	Complete Investigation (Food responsible for Outbreak)	Preventive Measures
Eg: For *Bacillus gastroenteritis*		Investigation of food, stools and faeces. Isolation of the microorganism	Infection due to accidental contamination or otherwise	Asepsis, prevent inadequate treatments, proper storage conditions

Interpretation of Report

This is done by the epidemiologist and conclusion is taken out for cause of the outbreak. Complete investigation of food borne disease outbreak is given as:

i) Name of the reporting officer

ii) Name of the local authority who is analyzing the complete outbreak

iii) Area/place of outbreak

iv) Date and time when suspected meal was taken

v) Number of persons' affected

vi) Number of people at risk indicating those who have developed symptoms)

vii) Incubation Period

viii) Symptoms

ix) Occupational/age group

x) Details of suspected meal (complete analysis of food)

xi) Foods which are eaten by affected persons

xii) Number of meal sittings and time

xiii) Methods of cooking

xiv) Time and temperature of storage of cooking

xv) General notes regarding the facilities and equipments

Minimum Infrastructure/ Materials Required

- Field Kit for field analysts to collect sample, medical equipment, sterile containers, sampling device, sterilized thermometer, lamps of alcohol, sterile wrapping foil, tapes for sealing, sterile paper, towels, ice boxes, insulated boxes for carrying samples.
- Laboratory- Facility to find the total plate count and types of microorganisms, glassware, pipettes, flask, media, laminar flow, stains. Chemicals, specific test kits for enumerating specific organisms.
- Data interpretation infrastructure.

WHO'S Golden Rule for Safe Food Production

1. Choose foods processed for safety.
2. Cook foods thoroughly.

3. Eat cooked foods immediately.
4. Store cooked foods carefully.
5. Reheat cooked foods thoroughly.
6. Avoid contact between raw and cooked foods.
7. Wash hands repeatedly.
8. Keep all kitchen surfaces meticulously clean.
9. Protect foods from insects, rodents and other animals.
10. Use pure water.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the main objectives for which investigation of any outbreak is done?

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2. Explain the various steps involved to carry out any investigation.

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3. State WHO's Golden rule for safe food production.

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9.7 LET US SUM UP

In this unit on food borne disease, we have examined what are the food borne disease and how to differentiate with food borne infections and intoxications. This includes study of various contaminants of food, namely, bacterial, non bacterial and toxic chemicals. We have also studied the importance of the investigation of food borne disease outbreak. The steps involved in the investigation were also studied. We have seen that food borne diseases maybe caused due to contaminated food and beverages. They are a common, distressing and sometimes life-threatening problem for millions of people all around the world. We also studied in the end the related golden rules for the prevention of such food borne disease outbreaks. Hence following good manufacturing practices (GMP's) and giving publicity to an outbreak and the explanation of its cause maybe helpful in educating and warning the public and avoiding further outbreaks.

9.8 KEY WORDS

Food Borne Disease : Disease caused by the consumption of contaminated foods or beverages

Food Borne Intoxication : Food borne disease caused due to ingestion of toxin already present in food.

Food Borne Infection : Food borne disease caused due to ingestion of causative organisms into the body where they multiply, grow and cause disease.

Exotoxin : Proteinaceous toxin produced by bacteria and excreted into surrounding environment

Endotoxin : Toxin produced by bacteria and excreted into surrounding environment after the cell lysis. Are mainly composed of polysaccharides.

9.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Food borne diseases are caused by consuming contaminated foods or beverages e.g., food borne infection and food borne intoxication.

2. Exotoxins are proteinaceous toxins produced by bacteria and excreted into surrounding environment.

   Endotoxins are toxins produced by bacteria and excreted into surrounding environment after the cell lysis (breaking of cell membrane), which are mainly composed of polysaccharides.

3. Chemical contaminants in food include fumigants, solvents like hexane, metallic contaminants such as antimony, arsenic, cadmium etc., insecticides, pesticides and growth regulators etc.

Check Your Progress Exercise 2

1. Non-bacterial food borne disease causing agents include viruses, rickettsias and parasites (*Trichinella, Entamoeba, Giardia, Ascaris*)

2. Jaundice is caused by Hepatitis A virus. through faecal-oral transmission. Foods associated are raw or partially cooked shellfish, raw milk, potato sandwiches and cold meat cuts.

3. Food borne parasites include:

   a) *Trichinells spiralis* (causes Trichinosis) characterized by nausea, abdominal pain, diarrhea and vomiting. Severe attack may cause paralysis, fever and severe pain.

   b) *Entamoeba histolytica* (causes amoebiasis) results in gastrointestinal distress, dysentery, ulcers and intestinal blockage.

   c) *Giardia lamblia* (causes giardiasis) results in severe gastroenteritis and intestinal problems.

   d) *Ascaris lumbricoides* causes ascariasis, resulting in digestive tract disturbance, intestinal disorder and blockage.

Check Your Progress Exercise 3

1. Objectives of food borne disease outbreak investigation are:

   - To prevent and control contamination of foods.
   - To know the disease causing agents.
   - To develop guidelines and take regulatory decisions.

2. Three steps in the investigation of any food borne disease outbreak:

   - **Field Analysis:** Collection of samples and data pertaining to the causes of outbreak in the particular area.

   - **Laboratory Analysis** dealing with the isolation of the causative organism from the various collected samples.

   - **Identification and the Interpretation of Report** involving the compilation of all facts and figures and stating the cause of outbreak and the possible causative measures to be taken.

3. WHO's Golden rule for safe food production states that:

   - Choose foods processed for safety
   - Cook foods thoroughly
   - Eat cooked foods immediately
   - Store cooked foods carefully
   - Reheat cooked foods thoroughly
   - Avoid contact between raw and cooked foods
   - Wash hands repeatedly
   - Keep all kitchen surfaces meticulously clean
   - Protect foods from insects, rodents and other animals
   - Use pure water

9.10 SOME USEFUL BOOKS

1. A manual entitled 'Procedures to Investigate Food borne Illnesses' (1976) has been written by the Committee on communicable Diseases Affecting Man in the International Association of Milk, Food and Environmental Sanitarians and provides excellent information on such food borne diseases and their outbreaks. A complete listing of diseases transmitted by foods, including etiologic agents, nature of the organism, incubation period, signs and symptoms, source or reservoir, epidemiology, foods involved and control measures can be found in Center for Disease Control (1976a).

2. Frazier, W.C. and Westoff, D.C. (1988) Food Microbiology, Tata McGraw-Hill Pub. Co., New Delhi. pp. 539.

3. Purohit, S.S. (1994) Microbiology-Fundamental and Application. 5th edn. Agro Botanical Publishers, Bikaner, India.

4. Srivastava, R.P. and Kumar, S. (1994) Fruits and Vegetable Preservation, International Book Distribution Co., Lucknow.

UNIT 10 FOOD INTOXICATIONS

Structure

10.0 OBJECTIVES

After reading this unit, you will be able to:

- discuss the causal organisms responsible for food borne intoxications;
- explain the toxins production by mold and bacteria (*Clostridium botulinum* and *Staphylococcus aureus*);
- the microbial toxins produced, the foods associated in intoxication, symptoms of the disease, diagnosis, conditions necessary for outbreak and preventive measures required will also be discussed; and
- know the naturally present toxins in the food products will also be accounted for.

After reading this unit you will be able to distinguish between food borne intoxications caused by the various microbiological agents and their preventive measures.

10.1 INTRODUCTION

We have already studied about the food borne diseases and their classification. Food borne intoxications are basically food borne illness caused due to ingestion of toxin produced my microorganisms (mycotoxins, bacterial toxins). Natural toxins present in food may also result in food poisoning in humans.

Food poisoning is also caused by consuming old, used, residual, fermented, spoiled, contaminated, toxic and bacteria infested food.

10.2 NATURAL TOXINS

Some plants and animals originate food contain toxic substances. Some pulses and legumes contain a number of toxic substances such as protease inhibitors, lathyrogens, and flavism causing agents, cyanogens, haemaglutinins and paponins which are discussed below:

a) Trypsin inhibitor is a proteinous in nature. It suppresses the release of amino acid. It thus interferes with the normal growth of animals fed with such pulses.

b) Haemglutinins are also proteins. They impair the absorption system.

c) Cynogenic glycosides cause cyanide poisoning on hydrolysis of the glycoside by the enzyme α-glucosidase, hydrogen cyanide is liberated. A cyanides content of 10-20 mg per 10 gm of pulses is considered safe. Many legumes excepting limabean (*Phaseolus lunatus*) contains cyanide within these limits.

d) Saponins are glycosides of high molecular weight. This has been reported in soyabean, swordbean and jackbean. Toxic saponins cause nausea and vomiting and can be removed by soaking the beans prior to cooking.

e) Alkaloids are known to occur in the seeds of many legumes but they are relatively innocuous.

f) Some compounds present in pulses appear to bind iodine thus producing a state of iodine deficiency in the thyroid and eventually goitre.

g) Lathyrism is a disease that paralyses the lower limbs. The disease is associated with consumption of *kesari dal* regularly as high as 300g daily. In lathyrism, the toxic substances interfere with formation of normal collagen fibers in the connective tissue.

h) A hemolytic factor in *Vicia faba* causes flavism. It is caused by eating broadbeans or by inhaling pollen of its flowers. Flavism is hemolytic anemia. In several cases, death may occur within 24-48 hours of the onset of the attack.

i) Oxalic acid, a constituent of rhubarb, spinach and beet may cause oxalic poisoning in certain individuals.

j) Some poisonous substances may also be present in some cereals and vegetables e.g. protease inhibitor in cereals and potatoes, saponins in spinach and asparagus and goitrogens in rapeseed mustard, cabbage and related species. Goitrogens cause hypothyroidism and thyroid enlargement

k) Tissues of certain marine animals contain toxic substances, which cause adverse responses when eaten. Some algae like *Gymnodinium* and *Gonyaulax* are toxic. Heating does not destroy these substances.

l) Algal or Planktonic Fish Poisonings: Fish poisoning can result from the ingestion of fish or shellfish that have fed upon algae toxic to human beings. Paralytic shellfish poisoning is caused by ingestion of shellfish such as scallops, clams and mussels which have consumed toxic dinoflagellates. Symptoms appear within 10min after ingestion and include gastrointestinal distress, parasthesia of the lips and fingertips followed by ataxia, muscular uncoordination and ascending paralysis. Death may occur within 2 to 12 hours from cardiovascular collapse or respiratory failure. The human lethal dose of toxin is considered to be 3 to 4 mg.

Prevention: Soaking, heating or fermentation of pulses can reduce or eliminate most of the toxic factors in them. Heat causes denaturation of the proteins responsible for trypsin inhibition and haemagglutination and of the enzyme causing hydrolysis of cyanogenic glycosides. Fermentation also destroys toxic factors and yield more digestible products of high nutritive value.

10.3 MYCOTOXINS

Fungi are a very diverse group of organisms and have a significant impact on the production, spoilage and safety of food. Molds have not only served to synthesize antibiotics but also to produce some foods. Fermented foods such as some cheese, soy sauce, *miso, tempeh* and other oriental delicacies are prepared with the help of molds.

It is well documented that some molds produce toxic substances. Some fungi elaborate the toxin in large macroscopic fruiting bodies; for example, the toxin produced by certain species of *Amanita*, a poisonous mushroom. Other fungi always grow and sporulate as parasites on living host plants, and sometimes will do so only on a specific host. *Claviceps* is an example of this group of fungi and it produces mycotoxins. In contrast to fungi that are parasitic on living plants another group of fungi is saprophytic and causes destruction of dead plants and animal material. There is abundance of the spores of these molds in atmosphere and are found to inhabit stored grain and dried products and hence have been referred to as "storage fungi". These molds include *Cladosporium, Fusarium, Penicillium, Aspergillus* and *Alternaria*.

Mycotoxins are secondary metabolites produced by molds on foodstuffs that causes illness or death when ingested by man or animals. The primary metabolites are those that are essential for growth whereas secondary metabolites are formed during the end of the exponential growth phase and have no apparent significance to the producing organism relative to growth. The mycotoxins commonly encountered in food are around one million times less toxic than most lethal of the botulism toxin. But long term chronic toxicity is of special concern because several of the mold metabolites are carcinogenic and influence the immune response of a number of animal species. The syndrome resulting from ingestion of toxin in a mold contaminated food is referred to as mycotoxicosis.

At the beginning of the last century, two major mycotoxicosis caused considerable suffering and mortality. They were alimentary toxic aleukia (ATA) in Russia, caused by consumption of corn contaminated with T-2 toxin produced by *Fusarium sporotrichoides* and yellow rice disease in Japan, associated with *Penicillium islandicum*. More recently, outbreaks of aflatoxicosis caused by consumption of corn contaminated with *Aspergillus flavus* were reported from India involving approximately 1000 people of whom nearly 100 died.

Several very important mycotoxins such as the sporidesmins, slaframine and tremorgens are associated with animal feeds and forages which affect the quality of meat and other animal products. It is also seen that mycotoxins present in animal feed get into human foods because they pass through the food chain in either their original or metabolized form.

When we store foods under inappropriate conditions they are susceptible to mold growth. Many mycotoxigenic species are able to produce several mycotoxins. It is likely, therefore, that contaminated foods will contain a cocktail of toxins that can interact synergistically.

Some major mycotoxins found in foods

Mycotoxin	Major Foods	Common Producing Species
Aflatoxins	Corn, groundnuts, figs, tree nuts	*Aspergillus flavus, A. parasiticus*
Aflatoxin M_1	Milk, milk products	(secreted by cow after metabolism of Aflatoxin B_1
Deoxynivalenol	Cereals	*Fusarium graminearum, F. culmorum*
Fumonisin	Corn	*Fusarium moniliforme*
Ochratoxin	Corn, cereals, coffee beans	*Penicillium verrucosum, Aspergillus ochraceus*
Patulin	Apple juice	*Penicillium expansum*
Sterigmatocystin	Cereals, coffee, beans, cheese	*Aspergillus versicolor*
Zearalenone	Corn, barley, wheat	*Fusarium graminearum*

10.3.1 Aflatoxin

Aflatoxins are the most widely studied of all mycotoxins. Knowledge of their existence dates from 1960, when more than 100,000 turkey died in England after eating peanut meal imported from Africa and South America. From the poisonous feed were isolated *Aspergillus flavus* and a toxin produced by this organism that was designated aflatoxin (*Aspergillus flavus* toxin- A-fla-toxin). These compounds are highly substituted coumarins, and at least 18 closely related toxins are known. Aflatoxin B_1 is the most important of this large family of compounds and is produced by *Aspergillus flavus, A. parasiticus* and *A.nominus*. The toxicity of the six most potent aflatoxins decreases in the following order: $B_1 > M_1 > G_1 > B_2 > M_2 \neq G_2$.

Occurrence: Aflatoxigenic molds can occur in warmer parts of the world and aflatoxicosis maybe produced in a wide range of tropical and subtropical food commodities such as figs, tree nuts and cereals. The most important crops are corn and groundnut, but it can also occur in temperate crops such as wheat. Although the production of aflatoxin initially was considered to be a problem in post harvest crops stored at inappropriate temperatures and water activities, it is now known that these compounds can be present in the field before harvest. *A.flavus* and *A. parasiticus* may infect healthy plants at a very early stage.

Biological effects: Aflatoxins are acute hepatotoxins and are known to be carcinogenic in some animal species as rat. Aflatoxin B_1 is acutely toxic to our species and is responsible for liver necrosis. The toxicological effect of the aflatoxins are influenced by their metabolism after intake into their body (Figure 10.1).

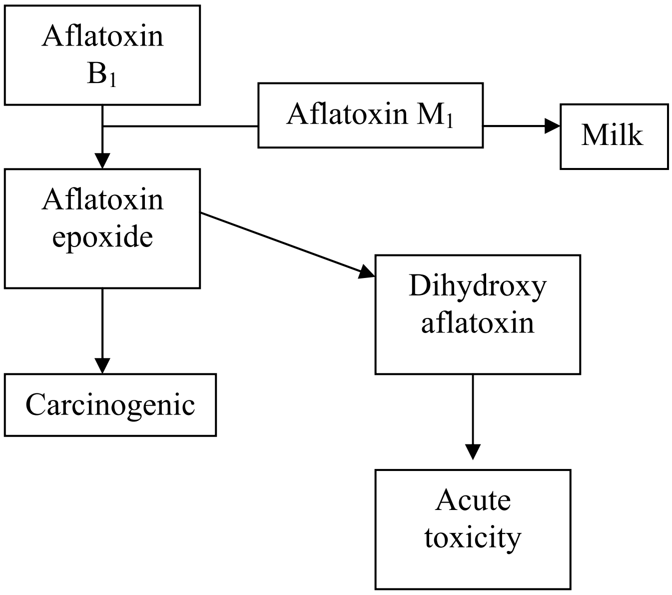

Figure 10.1: Representation of the metabolism of aflatoxin and its biological effects

When cows eat feed containing aflatoxin, aflatoxin M_1 and M_2 is excreted in the milk. Although M_1 and M_2 are less toxic than the parent compound B_1, M_1 retains its toxic and carcinogenic ability in many animals. The LD_{50} of AFB_1 for rats by the oral route is 1.2mg/kg and 1.5 to 2.0 mg/kg for AFG_1.

Control: Because aflatoxins are potentially widespread in occurrence and have an insidious combination of acute and chronic toxicity, it is prudent to control their presence in food. Many countries have legislation establishing maximum tolerance levels. Chemically treating the aflatoxin contaminated commodities like nuts maybe possible or to use technologically sophisticated equipment to sort and discard the contaminated units. It may also be possible to control the production of aflatoxin in the field by an integrated programme of agricultural management that may include plant breeding, improved irrigation and replacement of aflatoxigenic strains by non- aflatoxigenic strains of *A. flavus*.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are mycotoxins? How are they harmful?

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2. Give the biological effects of aflatoxin.

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3. List the various natural toxins present in food.

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10.3.2 Ochratoxin

Occurrence: Ochratoxin A is a phenylalanyl derivative of a substituted isocoumarin produced by *Penicillium verrucosum* in temperate climate and by several species of Aspergillus in warmer and tropical parts of the world. *Penicillium verrucosum* is especially associated with stored cereals although it has also been isolated from meat and fish, however the occurrence of ochratoxin A in meat products is usually due to transmission into muscle, kidney and blood in animal fed on contaminated animal feed such as barley. Ochratoxin may also be transferred from dietary intake into milk. *Aspergillus ochraceus* is common on coffee beans, spices, soybeans, groundnut, rice and corn. Ochratoxin is heat resistant and is not destroyed by roasting or autoclaving though the ochratoxin producing fungi are capable of growth and mycotoxin production at temperature below 10ºC.

Biological effects: It is associated with the chronic progressive kidney disease in humans known as Balkan endemic nephropathy. There is increased evidence that it can also be considered as a carcinogen with genotoxic property as well as a potent nephrotoxin. The availability of improved methods of analysis has demonstrated that ochratoxin is quite widespread in foods and its presence in human body fluids confirms that there is a significant exposure with the human population. Ochratoxin is immunosuppressive and inhibits protein biosynthesis. Ochratoxin A has been classified by the International Agency for Reseach on Cancer (IARC) as a possible human carcinogen. Low doses as 70μg/kg body weight can induce kidney tumors in male rats. Its oral LD_{50} in rats is 20 to 22 mg/kg, and it is both hepatotoxic and neprotoxic.

Control: Once ochratoxin A has been formed in a food, it is difficult to remove by most forms of food processing. Cooking with or without previous soaking removes a significant amount of ochratoxin from beans but does not lead to total destruction. Beans still contain 16% to 60% of the initial ochratoxin contamination and it seems probable that the material may have leached out rather than destroyed.

10.3.3 Patulin

It is a toxic and antibiotic metabolite produced by several species of *Penicillin, Aspergillus* and *Paeciliomyces* but the most important in the context of human food production is *P. expansum*, a soft rot pathogen of apple and pears. Patulin is an unsaturated lactose and is sensitive to sulphur dioxide and is unstable in alkali but stable in acid.

Occurrence: It is found in a range of foods based on fruits. Presence of patulin in fruit juice is a indication that the juice was extracted from poor quality fruit which is undesirable and should be avoided with good manufacturing practices. This mycotoxin has also been found in moldy bread, sausage, fruits (including bananas, pears, pineapples, grapes and peaches) and other products.

Biological activity: Patulin has an acute oral LD_{50} in rodents of about 30-50 mg/kg and has been shown to be teratogenic, immunotoxic and neurotoxic and to cause gastrointestinal disturbances in rats. Patulin is quite rapidly excreted from animals. It causes chromosomal aberrations in animal and plant cells and is a carcinogen.

Control: In apples molded by *Penicillium expansum*, most of the patulin is confined to the region of damaged tissue and simply removing the lesions reduces the toxin by 90%, but if 1cm around the lesion is also removed, no patulin is detectable in rest of the apple. Ascorbic acid has been reported to reduce levels of patulin. Although pasteurization (using high temperature, short time treatment of ten seconds at 90ºC) causes some reduction in patulin in fruit juices, it is only of the order of 20%, which is not sufficient to make a badly contaminated food product acceptable.

10.3.4 Alternaria Toxins

Several species of Alternaria (*A.citri, A. alternata, A.solani* and *A. tenuissima*) produce toxic substances that have been found in apples, tomatoes, blueberries and others. The toxins produced include alternariol, alternariol monomethyl ether, altenuene, tenuazonic acid and altertoxin-I.

10.3.5 Citrinin

This mycotoxin is produced by *Penicillin citrinum*, *P.viridicatum* and other fungi. It has been recovered from polished rice, moldy bread, country cured hams, wheat, oats, rye and other similar products. It is a known carcinogen.

10.3.6 Penicillic Acid

This mycotoxin has biological properties similar to patulin. It is produced by a large number of fungi, including many Penicillia as well as members of the *A.ochraceus*. One of the best producers is *P.cyclopium*, it has been found in corn, beans and other field crops. Its LD_{50} in mice by subcutaneous route is 100 to 300 mg/kg and it is a proved carcinogen.

10.3.7 Sterigmatocystin

These mycotoxins are structurally and biologically related to the aflatoxins, and like the latter, they cause hepatocarcinogenic activity in animals. Among the organisms that produce them are *Aspergillus versicolor*, *A. nidulans*, *A.rugulosus*. The LD_{50} for rats by intra-peritoneal injection is 60 to 65 mg/kg.

10.3.8 Fusarium Toxins

Another important genus of mycotoxin producers is *Fusarium,* many species of which produce members of the trichothecene family of mold metabolites like deoxynivalenol, neosolaniol and T-2 toxin etc.

Deoxynivalenol

Deoxynivalenol (DON) is a far more common, but much less toxic, trichothecene and is produced by species such as *F. graminearum* and *F. culmorum*. LD_{50} of DON is 70mg/kg. The trichothecenes are remarkably stable compounds, and DON will survive both dry milling and wet milling processes of corn. The baking of bread has relatively little effect on trichothecenes such as DON.

Zearalenone

It was first isolated as the agent responsible for vulvovaginitis in pigs, has very little acute toxicity, but there should be some concern about chronic exposure to a compound known to be estrogenic. It may be produced, together with DON and other trichothecenes, in a wide range of cereals including corn, barley and wheat.

Moniliformin

It was first obtained from a strain of *Fusarium moniliforme* isolated from southern leaf blight- damaged corn seed as a water soluble toxin. The LD_{50} for mice has been reported to be 20.9 mg/kg for females and 29.1 mg/kg for males. At toxic doses moniliformin causes rapid death without obvious overt cellular damage, although acute degenerative lesions in the myocardium are reported.

Fumonisins

The most recently characterized mycotoxins of any major significance in human health are the fumonisins produced by species of *Fusarium*, such as *F. moniliforme*. Like a number of mycotoxins, the fumonisins are relatively heat stable and would not be significantly destroyed by drying processes for corn or heat treatments used for the production of maize derivatives. Fumonisin B_1 is water-soluble is known to be responsible for equine encephalomalacia, porcine pulmonary edema syndrome and hepatic cancer in rats and maybe involved in the epidemiology of esophageal carcinoma in humans in southern Africa and parts of China.

The range of regulatory limits for mycotoxins

Mycotoxin	Regulatory Limit (µg/kg)
Aflatoxins in foods	0-50
Aflatoxin M1in milk	0-0.5
Deoxynivalenol in wheat	1000-4000
Ochratoxin A in foods	1-300
Patulin in apple juice	20-50
T-2 Toxin	100
Zearalenone	30-1000

10.4 BOTULISM

Botulism (Latin *botulus*, sausage) is a neuro-paralytic disease caused by the ingestion of food containing the neurotoxin produced by *Clostridium botulinum*.

10.4.1 Occurrence

Clostridium botulinum is an anaerobic, Gram-positive, spore forming, rod that produces the potent neurotoxin. The organism and its spores are widely distributed in nature and occur in both cultivated and forest soils, bottom of streams, lakes and coastal waters and in the intestinal tracts of fish and mammals and in viscera of shellfish.

On the basis of the serological specificity of their toxins, seven types of *Clostridium botulinum* are recognized: A, B, C, D, E, F and G. Types A, B, E, F and G cause disease in humans; type C causes botulism in fowls, cattle, mink and other animals and type D is associated with forage poisoning of cattle. Being a saprophyte, the organism seldom grows or produces toxic in the live animal; it can do so only by growing in food. The toxins are simple heat labile proteins and can be destroyed if heated at 80ºC for 10 minutes or longer.

C.botulinum does not produce the fully toxic molecule; instead a progenitor toxin is activated to its full toxicity by enzymes. The progenitor toxin is hydrolyzed to the highly toxic derivative toxin and is carried to target nerves where it binds to the synapses of motor neurons and prevents the release of the neurotransmitter acetylcholine. As a consequence, muscles do not contract in response to motor neuron activity and flaccid paralysis results.

10.4.2 Types and Symptoms

Different types of botulism are recognized: adult, infant and wound. A very small amount (a few nano grams) of toxin can cause illness.

Adult Botulism

Symptoms of botulism may develop anywhere between 12 and 72 hours after the ingestion of toxin containing foods. Symptoms include nausea, vomiting, fatigue, dizziness and headache, dryness of skin, mouth and throat, constipation, lack of fever, paralysis of muscles, double vision and finally respiratory failure and death. The duration of the illness is from 1 to 10 or more days depending upon host resistance and other factors.

Infant Botulism

In the adult form of botulism, preformed toxins are ingested; in infant botulism, viable botulinal spores are ingested and upon germination in the intestinal tract, toxin is synthesized. It is confined to infants under a year of age. High number of spores are found in the feces of infants during the acute phase of the disease. It appears that ingested endospores, which maybe present in honey or other baby foods, germinate in the infants intestine. *C.botulinum* then multiplies and produces the exotoxin. The infant becomes constipated, listless, generally weak and eats poorly. Death may result from respiratory failure.

Wound Botulism

It is the rarest form of botulism. The illness results when *C.botulinum* by itself or with other microorganisms infects a wound and produces toxins which reach other parts of the body via the bloodstream. Foods are not involved in this type of botulism.

10.4.3 Diagnosis

Although botulism can be diagnosed by clinical symptoms alone, differentiation from other diseases maybe difficult. The most direct and effective way to confirm the clinical diagnosis of botulism in the laboratory is to demonstrate the presence of toxin in the serum or feces of the patient or in the food which the patient consumed.

10.4.4 Foods Implicated in Botulism

The types of foods involved in botulism vary according to food preservation and eating habits in different regions. Any food that is conducive to outgrowth and toxin production, that when processed allows spore survival, and is not subsequently heated before consumption can be associated with botulism. Almost any type of food that is not very acidic (pH above 4.6) can support growth and toxin production by *C.botulinum*. Botulinal toxin has been demonstrated in a considerable variety of foods, such as canned corn, peppers, green beans, soups, asparagus, mushrooms, spinach, tuna fish ham, sausage and smoked and salted fish.

10.4.5 Conditions Necessary for Outbreak

The following conditions are necessary for an outbreak of botulism:

1. Presence of spores of *C.botulinum* of type A, B or E in foods being consumed or being processed in some other way

2. A food in which the spores can germinate and the clostridia can grow and produce toxin

3. Survival of the spores of the organism eg: because of inadequate heating in canning or inadequate processing otherwise

4. Environmental condition after processing that will permit germination of the spores and growth and toxin production by the organism

5. Insufficient cooking of the food to inactivate the toxin

6. Ingestion of the toxin-bearing food

10.4.6 Prevention and Control

The prevention and cure of botulism involves:

1. Strict adherence to safe food-processing practices by the food industry
2. Educating the public on safe home-preserving (canning) methods for foods
3. Not feeding honey to infants younger than 1 year of age
4. Not tasting any processed food having a questionable odor
5. Recommended treatment for botulism includes early administration of botulinal antitoxin and intensive supportive care (including mechanical breathing assistance).

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the causative organism and the foods associated with botulinal food intoxication?

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2. Differentiate between adult and infant botulism.

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3. List down the various mycotoxins associated with food.

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10.5 STAPHYLOCOCCAL FOOD POISONING

Staphylococcal food poisoning results from consumption of food containing enterotoxin produced by enterotoxigenic strains of *Staphylococcus aureus*. It is caused by ingestion of improperly stored or cooked food (particularly foods such as ham, processed meats, chicken salad, pastries and ice cream) in which *S.aureus* has grown.

S.aureus is a Gram-positive coccus, very resistant to heat, drying and radiation. If the bacteria are allowed to incubate in certain foods, they produce heat-stable enterotoxin that render the food dangerous. Six different enterotoxins have been identified and are designated as A, B, C, D, E and F.

10.5.1 Occurrence

Staphylococci exist in air, dust, sewage, water, milk and food or on food equipment, environmental surfaces, humans and animals. Humans and animals are the primary reservoirs. Staphylococci are present in the nasal passages and throats and on the hair and skin of 50 percent or more of healthy individuals. A wide range of foods maybe involved in Staphylococcal food poisoning including ham, turkey, chicken and chicken salad, baked products, especially filled pastries, table ready-meats (sausage etc.), precooked frozen foods and dairy products.

S.aureus cells are relatively more resistant than many gram negative food spoilage organisms. Human intoxication is caused by ingesting enterotoxins produced in food by strains of *S.aureus,* usually because the food has not been kept hot enough (60ºC, or above) or cold enough (7.2ºC, or below). In frozen foods they may survive at –10ºC. In general, survival of *S.aureus* is best in foods that contain high concentration of sugars, eggs and buffering component such as phosphates and protein. Salt concentration less than 9.5%, temperature more than 20ºC and a pH in the range 6-8 are favourable for growth and enterotoxin formation.

10.5.2 Symptoms

A toxin dose of less than one micro gram in contaminated food will produce symptoms of staphylococcal intoxication. This toxin level is reached when *S. aureus* populations exceed 100,000 per gram. Symptoms of staphylococcal food poisoning usually develop with 1-6 hours of ingestion of contaminated food. Typical symptoms include severe abdominal pain, diarrhoea, vomiting, sweating, headache, prostration, nausea and sometimes a fall in body temperature. The mortality rate of staphylococcal food poisoning is negligible among healthy individuals.

10.5.3 Diagnosis

Diagnosis is based on the symptoms or laboratory diagnosis of the bacteria from leftover foods and from the stool cultures of victims. Enterotoxin maybe detected in foods by animal toxicity tests.

10.5.4 Foods Incriminated

Foods that are frequently incriminated in staphylococcal food poisoning include meat and meat products, poultry and egg products, egg, tuna, chicken, potato and macaroni, bakery products like cream-filled pastries, cream pies, chocolate eclairs, sandwich fillings, milk and dairy products. Foods that require considerable handling during preparation and that are frequently involved in staphylococcal food poisoning.

10.5.5 Conditions Necessary for Outbreak

The following conditions are necessary for an outbreak of staphylococcal food poisoning:

1. The food must contain enterotoxin producing staphylococci.
2. The food must be a good culture medium for growth and toxin production by the staphylococci.
3. The temperature must be favourable for growth of the cocci and enough time must be allowed for production of enterotoxin.
4. The enterotoxin bearing food must be ingested.

10.5.6 Prevention and Control

Staphylococcal food poisoning can be prevented by:

1. Avoiding contamination of food with *S.aureus.*
2. Prevention of growth of staphylococci by adequate refrigeration of foods and adjustment of more acid pH.
3. Killing staphylococci in susceptible foods by heating rapidly to 65-70ºC for 12-15 minutes.
4. Good personnel hygiene- exudates from skin lesions (pimples, boils) and nasal discharges of food handlers are rich sources of staphylococci and should be avoided.
5. Prolonged storage at room temperature of filled pastries, meat, salads and similar products that receive only a minimal heat treatment should be avoided.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the conditions favouring the outbreak of Staphylococcal food poisoning?

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2. Give the preventive and control strategies of Staphylococcal food poisoning.

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10.6 LET US SUM UP

The unit deals with the food borne intoxications which are caused by ingestion of toxins produced from molds (*Aspergillus niger*, *Penicillium* sp.) or bacteria (*C.botulinum* and *S. aureus*). An effort has been made to point out the major conditions required for outbreak of the disease along with the diagnosis and the preventive measures required to prevent the outbreak of disease.

10.7 KEY WORDS

Food Borne Intoxication : It is the food borne disease caused due to ingestion of food containing the toxin.

Mycotoxins : These are secondary metabolites produced by filamentous fungi (molds) on food and feedstuffs that cause illness and death when ingested by man or animals.

Aflatoxin : This is the mycotoxin elaborated by *Aspergillus flavus*.

Ochratoxin : Mycotoxin produced by *Penicillium verrucosum*.

Patulin : Mycotoxin produced by species of *Penicillin*, *Aspergillus* and *Paeciliomyces*.

Citrinin : Mycotoxin produced by *Penicillin citrinum*.

Botulism : Food borne intoxication caused due to consumption of food containing toxin, produced by *Clostridium botulinum*.

Staphylococcal Food Poisoning : Food borne intoxication caused due to consumption of food containing toxin, produced by *Staphylococcus aureus*.

LD_{50} Dose : Lethal Dose of toxin at which minimum 50% of the population may get infected by the toxin.

Zearalenone : Mycotoxin produced by *Fusarium graminearum* and *F. tricinctum.*

10.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.
   - Mycotoxins are toxins (secondary metabolites) produced by filamentous fungi on food and feedstuffs that cause illness when ingested
   - Cause hepatotoxicosis, carcinogenesis, liver cirrhosis etc.
2. Biological effects of aflatoxin include hepatotoxicosis, carcinogenesis and liver cirrhosis.
3. Natural toxins in foods: Trypsin inhibitor, haemaglutenins, cyanogenic glycosides, saponins, alkaloids, goitrogens .

Check Your Progress Exercise 2

1.
   - Botulism is caused by the bacteria *Clostridium botulinum*.
   - All low acid foods can support growth and toxin production by *Clostridium botulinum*.
   - Unheated foods are causative agents e.g.: canned foods (canned corn, peppers, green beans, soups), sausages, smoked fish etc.
2.
   - Adult Botulism is prevalent amongst adults whereas Infant Botulism is prevalent in infants of less than one year of age.
   - Caused due to ingestion of viable spores of *C. botulinum.*
   - Symptoms in adults: Nausea, vomiting, fatigue, dizziness, headache, dryness of skin and respiratory failure
   - Symptoms in infants: Constipation, weakness and loss of appetite and in severe cases death
3. Mycotoxins associated with foods are:
   - Aflatoxins (produced by *Aspergillus flavus*)
   - Ochratoxin (produced by *Penicillium verrucosum*)
   - Patulin (*P. expansum*)
   - Citrinin (*Penicillin citrinum*)
   - Alternaria toxins (*Alternaria* sp.)
   - Penicillic acid (*P.cyclopium*)
   - Sterigmatocystin (*Aspergillus versicolor*)
   - Fusarium toxins (*Fusarium* sp)

Check Your Progress Exercise 3

1. Conditions necessary for outbreak of Staphylococcal food poisoning:

- Presence of viable staphylococcal bacteria in the food
- Growth and toxin production in food
- Toxin containing food must be ingested into the body

2. To prevent and control Staphylococcal food poisoning:

- Avoid contamination of foods
- Kill organism by heating, refrigeration
- Personnel hygiene
- Adequate cooking
- Proper storage

10.9 SOME USEFUL BOOKS

1. Defigueiredo, M.P. and Splittstoesser, D.F. (1976) Food Microbiology: Public Health and Spoilage Aspects, AVI Publishing Co. Inc., Westport, Connecticut. pp 492.

2. Jay, J. (1996) Modern Food Microbiology, CBS Publishers, New Delhi. pp701.

UNIT 11 BACTERIAL FOOD INFECTIONS

Structure

11.0 OBJECTIVES

After reading this unit, you will be able to:

- describe major bacteria causes food born infections
- explain the mode of transmission of the food borne infection, symptoms and preventive measures.

11.1 INTRODUCTION

Food infection occurs when a pathogen enters the gastrointestinal tract and multiplies. Microorganisms can penetrate into the intestinal mucosa and grow there, or they can pass through other systemic organs. Infections are characterized by a delay in the appearance of gastrointestinal disturbance while the pathogen increases in numbers or affects invaded tissue. There is also usually a fever, one of the body's general responses to an infective organism.

Foodborne infections remain a major public health problem. The Council for Agricultural Science and Technology estimated in its 1994 report, *Foodborne Pathogens: Risks and Consequences*, that as many as 9,000 deaths and 6.5 to 33 million illnesses in the United States each year are food-related.

11.1.1 Zoonotic Diseases

The World Health Organization defines Zoonoses (Zoonosis, sing.) as "Those diseases and infections which are naturally transmitted between vertebrate animals and man".

Mode of transmission: Feces, urine, saliva, blood, milk, via aerosol, oral, contact with bedding or animals, etc.

Approximately 150 zoonotic diseases are known to exist. Wildlife serves as a reservoir for many diseases common to domestic animals and humans. Persons working with wildlife should be alert to the potential for disease transmission from animals. Generally, disease is more easily prevented than treated. Many zoonotic diseases are so common in nature, so rare in humans, or so mild in their symptoms, that wild animals pose a minimal health risk to people.

Zoonotic diseases include:

- Those which can be transmitted directly from animals to humans (e.g. rabies).
- Diseases that can be acquired indirectly by humans through ingestion, inhalation or contact with infected animal products, soil, water, or other environmental surfaces which have been contaminated with animal waste or a dead animal (e.g. salmonellosis, leptospirosis, anthrax). *Campylobacter* infection is mainly found in chicken meat. Listeriosis and *E.coli* gastroenteritis are two other common infections caused by zoonotic agents. All these will be discussed one by one.
- A disease which has an animal reservoir, but requires a mosquito or other arthropod to transmit the disease to humans (e.g. St. Louis encephalitis, Rocky Mountain spotted fever).

11.2 SALMONELLOSIS

Salmonellosis is the most reported zoonotic disease in European countries. Salmonellosis (*Salmonella* gastroenteritis) results from the ingestion of foods that contain significant numbers of viable cells of the members of the genus *Salmonella*. It is the most frequently occurring food borne infection.

Salmonella are small gram negative, motile, non-spore forming rods that ferment glucose, usually with gas, but usually do not ferment lactose or sucrose. They are widely distributed in nature, with humans and animals being their primary reservoir. Generally large number of salmonellae typically 10^6 to 10^9 bacterium must be ingested to cause illness.

Occurrence: The initial source of the bacteria is the intestinal tract of animals such as birds, reptiles, farm animals, humans and occasionally insects. As intestinal form, the organisms are excreted in feces from which they maybe transmitted by insects and other living creatures to a large number of places, polluted water and contaminated food. The organism may get transferred from actual infected cases of the disease or from carriers. A carrier is defined as a person or an animal that repeatedly sheds bacteria, usually through feces, without showing any signs or symptoms of the disease. Infected rodents, rats and mice may contaminate unprotected foods with their feces and thus spread *Salmonella* bacteria. Flies may play an important role in the spread of *Salmonella*, especially from contaminated fecal matter to foods. Humans acquire the bacteria from contaminated food such as beef products, poultry, eggs, egg products or water.

Symptoms: The susceptibility of humans varies with the species and strains of the organism and the total number of bacteria ingested. A longer incubation period usually distinguishes salmonellosis from staphylococcus poisoning: usually 12-36 hours for the former and about 2-4 hours for the latter. The principle symptoms of a salmonella gastroenteritis infection are nausea, vomiting, abdominal pain and diarrhoea that usually appear suddenly. This may be preceded by a headache and chills. Other evidences of the disease are watery, greenish-fowl-smelling stools, prostration, muscular weakness, faintness, usually a moderate fever, restlessness, twitching and drowsiness. The mortality is less than 1%. Intesibility may vary from slight discomfort and diarrhoea to death in 2 to 6 days. About 0.2 to 5.0% of the patients may become carriers of the *Salmonella* organism. During the acute phase of the disease, as many as one billion salmonellae can be found per gram of feces.

Associated foods: Raw meats, poultry, eggs, milk and dairy products, fish, shrimp, coconut, sauces and salad dressings, cake mixes, cocoa, peanut butter and chocolate.

Conditions Necessary for Outbreak

The food must contain or become contaminated with the *Salmonella* bacteria.

These bacteria must be there in considerable numbers i.e., food should be a good culture media, temperature favourable and enough time allowed for appreciable growth.

The viable organism must be ingested.

Prevention of Outbreak: The control of food borne salmonella infection requires the following:

1. Preventing food contamination by human carriers, especially food handlers.
2. Avoiding the use of animal products from domestic livestock that are grossly infected with salmonellae.
3. Avoiding the use of food ingredients that contain salmonellae.
4. Processing all foods susceptible to *Salmonella* contamination at time-temperature schedules sufficient to destroy the organism. Heating foods so that all portions reach 66ºC for 12-15 minutes will assure destruction of even most resistant *Salmonella* types.
5. Refrigerating all foods susceptible to *Salmonella* contamination and avoiding prolonged holding of these foods at room temperature.

11.3 ENTEROPATHOGENIC *ESCHERICHIA COLI*

Escherichia coli is generally regarded as part of the normal flora of the human intestinal tract and that of many animals. Serotypes of *E. coli* which have been implicated in human diarrhoeal diseases or food poisoning outbreaks and have been designated enteropathogenic *E. coli* (EEC). They grow over a wide range of temperatures, 20-40ºC with a minimum growth temperature at 10ºC and an optimum at 37ºC. Heating at 65ºC for 15-20 minutes is lethal. The pH range for growth is 4.2-8.50, with an optimum in the range of pH 7.2-7.5. *E. coli* will grow in the presence of 5.0% salt at 37ºC but 10% is inhibitory.

Symptoms: The *E. coli* gastroenteritis syndrome is caused by the ingestion of 10^6-10^{10} viable cells/g that must colonize the small intestine and produce enterotoxin. The syndrome is characterized primarily by non-bloody, watery diarrhoea without inflammatory exudates in stools. Incubation time of disease is around 2 days after eating the contaminated food and may last for 8 days. Common symptoms included are cramps, chills, vomiting, aches and headache.

Associated Foods: *E. coli* is the etiologic agent of food poisoning involves variety of foods such as cream pie, mashed potatoes, cream puffs and creamed fish. Other *E. coli* food poisoning outbreaks have been attributed to the consumption of milk, cheese, ice cream, meats, fish and macaroni. *E. coli* is relatively sensitive to destruction by drying or freezing but some survivors may exist for extended periods.

“Enteropathogenic” strains colonize in the small intestine and cause acute gastroenteritis in newborns and in infants up to two years of age. “Enteroinvasive” strains invade the epithelial cells of large intestine and cause diarrhoea in older children and adults. “Enterotoxigenic” (enterotoxin producing) strains produce one or both of two different toxins:a heat stable toxin (ST) and a heat labile toxin (LT). Both toxins cause diarrhoea in adults and infants. Enterotoxigenic strains of *E. coli* are often associated with Travellers’ diarrhoea, a common disease contracted by tourists when visiting developing countries. Diagnosis of travellers’ disease is based on the past travel history and symptoms. Laboratory diagnosis is by isolation of the bacteria from feces. Treatment is with fluid and electrolytes. Other strains of *E. coli* which are usually harmless in their normal habitat (the intestine) can cause disease when they gain access to other sites or tissues. These diseases include urinary tract infections, septic infections, bacteremia, meningitis, pulmonary infections, abscesses, skin and wound infections.

Prevention and Control: Involves avoiding contaminated food and water that have high coliform counts, avoiding unpasteurized juices, washing fresh fruits and vegetables thoroughly before eating raw, using adequate cooking procedures for destruction and prompt refrigeration. Most people recover from *E. coli* infection within 5-10 days without treatment. Antibiotics and antidiarrhoeal drugs are usually not helpful.

11.4 *BACILLUS CEREUS* GASTROENTERITIS

Bacillus cereus is not a common cause of food poisoning. It is a Gram positive, aerobic, spore forming rod shaped bacteria normally present in soil, dust and water. The bacterium has a minimum growth temperature around 4-5ºC, with maximum around 48-50ºC. Optimum pH range for growth is 4.9 to 9.3.

Symptoms: Extremely large numbers (10^8 per gram) of viable cells of *B.cereus* must be ingested to develop signs and symptoms of the syndrome. The bacterial cells produce intoxication characterized by acute abdominal pain, flatulence and watery diarrhoea. Headache and dizziness are common, dehydration and prostration may occur but nausea, vomiting, fever and chills are rare. The illness appears within 6-15 hours after consumption of food and the symptoms usually last less than 24 hours.

Associated Foods: Vehicle foods consist of cereal dishes that contain corn and corn starch, mashed potatoes, vegetables, minced meat, liver sausage, milk, cooked meat. Food mixtures such as sauces, puddings, soups, pastries and salads have frequently been incriminated in outbreaks.

11.5 CHOLERA

Cholera is caused by the gram negative, *V. cholerae*, which is acquired by ingesting food or water contaminated by fecal material from patients or carriers (shellfish and plankton may be the natural reservoir).

Symptoms: Once the bacteria enter the body, the incubation period is from several hours to three or more days. An infective dose of around one million organisms should be ingested to cause illness. The bacteria adhere to the small intestine wall, where they secrete the cholera enterotoxin, choleragen. As a result, there is hyper secretion of water and chloride ions, while inhibiting absorption of sodium ions. The patient experiences an outpouring of fluid and electrolytes with associated abdominal muscle cramps, vomiting, fever and watery diarrhoea. The diarrhoea can be so profuse that a person can lose 10-15 liter of fluid during the infection. Death may result from the elevated concentration of blood proteins, caused by reduced fluid levels, which leads to circulatory shock and collapse. Onset of the illness is generally sudden, with incubation periods varying from 6 hours to 5 days.

Associated Foods: Cholera is generally a disease spread by poor sanitation, resulting in contaminated water supplies. Sporadic cases occur when shellfish harvested from fecally polluted coastal waters are consumed raw.

Diagnosis: Cholera can be confirmed only by the isolation of the causative organism from the diarrheic stools of infected individuals.

Prevention: Following recommendations are there to prevent cholera outbreak:

- Drink only water that you have boiled or treated with chlorine or iodine. Other safe beverages include tea and coffee made with boiled water and carbonated, bottled beverages with no ice.
- Eat only those foods that have been thoroughly cooked and are still hot, or fruit that you have peeled yourself.
- Avoid undercooked or raw fish or shellfish.
- Make sure all vegetables are cooked, avoid salads.
- Avoid foods and beverages from street vendors.

A simple thumb rule is **“Boil it, cook it, peel it, or forget it”**.

Control: Individuals infected with cholera require oral rehydration therapy with NaCl plus sucrose, sodium bicarbonate and potassium chloride to stimulate water uptake by the intestine. The antibiotics of choice are a tetracycline or aproflaxin. The most reliable control methods are based on proper sanitation, especially of water supplies. The mortality rate without treatment is often over 50%. Medical treatment to prevent dehydration prevents all complications.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Briefly discuss the Salmonella food infection.

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2. How do you prevent food borne infection?

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11.6 *VIBRIO PARAHAEMOLYTICUS* GASTROENTERITIS

While most other known food poisoning syndromes may be contracted from a variety of foods, *V. parahaemolyticus* gastroenteritis is contracted almost solely from seafood. It can grow in presence of 1-8% NaCl, in pH range 9.8-11.0 with 7.6-8.6 being optimum.

Symptoms: A total of greater than one million organisms may cause disease. Symptoms of intoxication which range from mild to severe and fatal, include abdominal pain, which maybe intense; a burning sensation of the stomach; vomiting and diarrhoea with watery stools and sometimes bloody discharges; fever. The mean incubation period is in range of 3-76 hours after the ingestion of the organism.

Associated foods: Vehicle foods for outbreak are raw, improperly cooked, or cooked, recontaminated seafoods, such as, oysters, shrimps, crabs, lobsters, clams and related shellfish. Cross-contamination may lead to other foods as vehicles. Improper refrigeration of seafoods contaminated with this organism will allow its proliferation, which increases the possibility of infection.

Diagnosis: Diagnosis of gastroenteritis caused by this organism is made by culturing the organism from the diarrheic stools of an individual.

Prevention: Consumption of raw or improperly cooked seafoods should be avoided as they are susceptible to infection by *V. parahaemolyticus.*

11.7 SHIGELLOSIS

Shigellosis or bacterial dysentery, is caused by facultatively anaerobic, gram-negative, non-spore forming, rod-shaped organisms belonging to the genus *Shigella* within the family enterobacteriacae. In general, shigellosis is a self-limiting disease, lasting 5 to 6 days if untreated, however in young malnourished children, the elderly and the immuno compromised (eg, AIDS patients), the disease may be fatal. It is estimated that shigellosis is responsible for the death of 500,000 children worldwide each year. There are many points of similarity between *Shigella* and *Salmonella*. They dwell primarily in the gastrointestinal tract, with optimum temperature of 37ºC, grow both aerobically and anaerobically they grow freely in warm, bland, moist foods. But unlike salmonellae, the shigellae have no flagella and thus are non-motile. The species involved are *Shigella sonnei, S. dysenteriae, S. flexineri* and *S. boydii*. As few as 10cfu of *S. dysenteriae* are known to initiate infection in susceptible individuals. The illness caused by *Shigella* accounts for less than 10% of the reported outbreaks of food borne illness in US. The organisms tolerate salt concentration of 5-6% and are relatively heat sensitive.

Occurrence: Poor personal hygiene is a common factor in food borne shigellosis, with shellfish, fruits and vegetables, chicken and salads being prominent among vehicle foods. The prominence of these foods is due to the fecal-oral route of transmission. Outbreaks have been also traced to foods such as chocolate pudding, salads.

Symptoms: Pathogenicity involves the release of lipopolysaccharide endotoxin which infects the intestinal mucosa. Shigellosis ranges from fairly mild to very severe and fatal. The onset is usually abrupt, requiring from 1-7 days of incubation, but sometimes requiring as many as 14 days. Symptoms are abdominal pain and cramps caused by inflammation of mucus surface of large intestine, nausea, diarrhoea, vomiting, elevated temperature. The mortality associated with *S. dysenteriae* infection is around 20% but it is much lower with other species. In severe instances, excessive diarrhoea leads to electrolytic imbalance in the bloodstream and ulceration in large intestine. There may be kidney failure, jaundice and persistent internal bleeding. The infection is localized and organs other than the large intestine are not invaded.

Diagnosis: Serological identification of culture isolated from stool helps to diagnose the disease.

Prevention and Control: The control of *Shigella* food borne infection is similar to that of salmonellae; avoiding contamination of foods by animal or human carriers or their excrement, thorough cooking and prompt cooling. Proper personal hygiene should be maintained. In severe cases of shigellosis, dehydration of the body may necessitate intravenous replacement of fluid with electrolytes. Ampicillin antibiotic can decrease the duration of the disease.

11.8 CAMPYLOBACTERIOSIS

It is caused by *Campylobacter jejuni*, a Gram negative rod. It is a microaerophillic organism, which means it has a requirement for reduced levels of oxygen. It is often isolated from healthy cattle, chickens, birds and even flies. It is also sometimes present in non-chlorinated water sources such as streams and ponds. The bacteria cause between 5 and 14 per cent of all diarrhoeal illnesses worldwide. C. jejuni primarily affects children under 5 years old and young adults (15-29 years old).

Symptoms: *C. jejuni* infection causes diarrhoea, which may be watery or sticky and can contain blood and fecal leukocytes (white cells). Other symptoms often present are fever, abdominal pain, nausea, headache and muscle pain. The illness usually occurs 2-5 days after ingestion of the contaminated food or water. Illness generally lasts 7-10 days, but relapses are not uncommon (about 25% of cases). Most infections are self-limiting and are not treated with antibiotics. The infective dose of *C. jejuni* is considered to be 400-500 bacteria.

Associated Foods: *C. jejuni* frequently contaminates raw chicken. Survey shows that 20-100% of retail chickens are contaminated. Many healthy chickens carry these bacteria in their intestinal tracts. Raw milk is also source of infections. The bacteria are often carried by healthy cattle and by flies on farms. Non-chlorinated water may also be a source of infection.

Prevention: the various ways to prevent campylobacteriosis are:

- Wash hands before preparing foods.
- Wash hands immediately after handling raw poultry or other meat.
- Proper cooking of chicken to internal temperature of 170ºC.
- Drink pasteurized milk and chlorinated water.
- Wash hands after handling pet feces or visiting zoos.

Control: If a person is suffering from campylobacteriosis, he can take an antibiotic such as ciproflaxin or azithromycin. Erythromycin also helps to treat the diarrhoea. Those having diarrhoea should take plenty of water.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give the causative organism and symptoms of Bacillary Dysentry.

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2. What are the symptoms and foods associated with campylobacteriosis?

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11.9 YERSINIOSIS (*YERSINIA ENTEROLYTICA* INFECTION)

In the genus Yersinia, 11 species are recognized, including *Y. pestis*, the cause of plague. The species of primary interest in foods is *Y. enterolytica*.

Occurrence: *Y. enterolytica* is widely distributed in the terrestrial environment and in lake, well and stream waters which are sources of warm-blooded animals. It is more animal adapted and is found more often among human isolates than the other species.

Animals from which *Y. enterolytica* has been isolated include cats, birds, dogs, beavers, guinea pigs, rats, camels, horses, chickens, deer, cattle, swine, fish and oysters. It is widely believed that swine constitutes the single most common source of *Y. enterolytica* in humans.

In addition to gastroenteritis, this organism has been associated with human pseudoappendicitis, mesenteric lymphadenitis, reactive arthritis, colon and neck abscesses and cholecystis. It has been recovered from urine, blood, cerebrospinal fluid and the eyes of infected individuals. It is also recovered from the stools of gastroenteritis victims.

Associated Foods: The organism has been isolated from cakes, vacuum-packaged meats, seafood, vegetables, milk and other food products. It has been isolated also from beef, lamb and pork. Of all sources, swine appears to be the major source of pathogenic for humans.

Symptoms: Symptoms of the gastroenteritis syndrome develop several days following ingestion of contaminated foods and are characterized by abdominal pain and diarrhoea. Children appear to be more susceptible than adults and the organism may be present in stools for up to 40 days following illness. A variety of systemic involvements may occur as a consequence of the gastroenteritis syndrome.

The usual symptoms, including severe abdominal pain, fever and diarrhoea occur 24 to 36 hours after consumption of the product. The abdominal discomfort is quite specific and usually manifests itself as a sharp pain in the lower right quadrant of the abdomen. For this reason it has frequently been described as pseudoappendicitis.

Although the organism has been isolated from many foods, there have been relatively few food-borne outbreaks attributed to *Y. enterolytica*. The isolation from pasteurized milk is probably the result of post pasteurization contamination. The unique characteristic of the organism is its ability to grow at commercial refrigeration temperatures, i.e. less than 5ºC.

11.10 *LISTERIA MONOCYTOGENES* INFECTION (LISTERIOSIS)

Listeria monocytogenes is a gram-positive, motile, non-sporing rod. It is widely distributed in nature and can be found on decaying vegetation and in soils, animal feces, sewage, silage and water. In cattle it can result in abortion and mastitis and the infected animals shed the organism in milk. Other infected organisms including sheep and chicken can serve as source of the organism in the food supply.

Syndrome: Listeriosis in humans is not characterized by a unique set of symptoms since the course of the disease depends upon the state of the host. Non-pregnant healthy individuals who are not immunosuppressed are highly resistant to infection by *L. monocytogenes*. When susceptible adults contract the disease, meningitis and sepsis are the most commonly recognized symptoms. Pregnant females who contract the disease may not present any symptoms, but when they do, they are typically mild and influenza-like. Abortion, premature birth or still birth is often the consequence of listeriosis in pregnant females. When a newborn is infected at the time of delivery, listeriosis symptoms typically are those of meningitis and they begin at 1 to 4 weeks after birth, although a four week incubation has been recorded. The usual incubation time in adults ranges from one to several weeks.

Since *L. monocytogenes* can grow over the temperature range of about 1° to 45°C and the pH range 4.1 to around 9.6, it maybe expected to survive in foods for long periods of time.

Some of the ways in which *L. monocytogenes* is disseminated throughout the environment, along with the many sources of the organism to humans, are illustrated below.

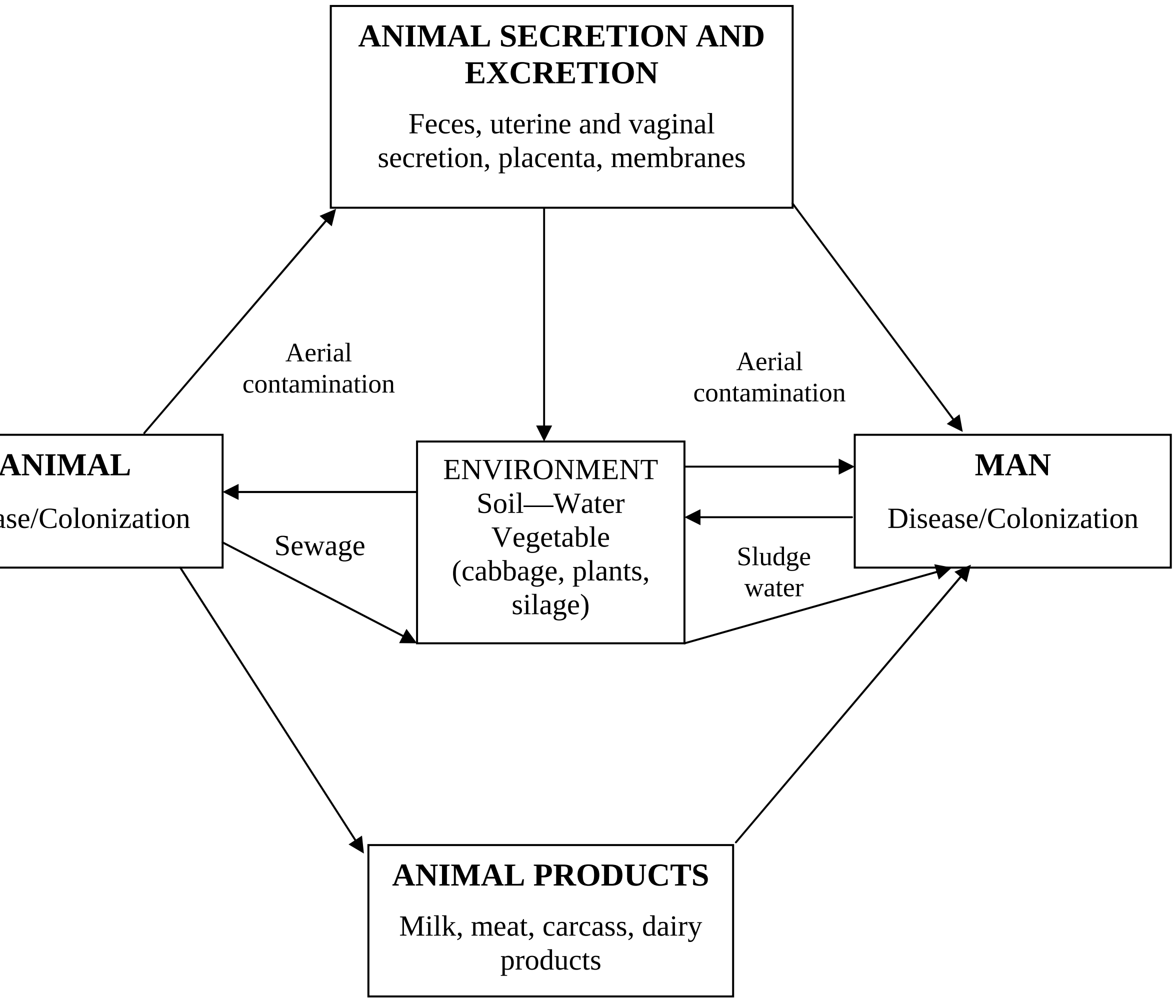

Figure 13.1: Ways in which *L. monocytogenes* is disseminated in the environment, animals, foods and humans

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is yersiniosis? Give its symptoms.

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2. How is *L. monoctogenes* infection transmitted?

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Tips on Foodborne Illness Prevention for Consumers

Salmonella, Escherichia coli, Shigella, Campylobacter, Listeria, and the list goes on. Interesting names for little organisms that can cause big bad health problems. Bacterial foodborne diseases have become an acute public health crisis in this country, responsible for about 6.5 to 81 million illnesses and 9,000 deaths per year. While it is unrealistic to think there would ever be a zero level of contamination in our food supply, 90% - 95% of all foodborne bacterial illness is preventable. You cannot see, taste, or smell most bacterial foodborne problems, so here's what you can do to safeguard your family.

In General:

- Don't ever consume products such as unpasteurized milk or unpasteurized apple cider or other foods made with unpasteurized products. Thoroughly cook all meat, poultry and fish products. Meats are thoroughly cooked at 71ºC, poultry at 82ºC, and fish when they easily flake with a fork.
- Break open any hamburger patties (other ground meat dishes such as meatballs, too) prior to ingestion to make sure there is no pink meat and that the juices run clear.

When Dining Out

- Hot food should be served hot and cold food should be served cold or send it back.
- Talk to the restaurant manager. Find out how much importance they place on sanitary and bacterial issues. Do they routinely use thermometers? Do

they own and routinely use a thermocouple which is a special thermometer used to accurately test temperatures of thin food? If you receive undercooked food (especially ground meat) express your displeasure and nicely inform them of the risks. Let them know how important food safety is to you.

When Shopping

- Take great care to avoid dripping raw juice from meat, poultry or fish onto your hands or other foods, especially produce. Raw juices often contain bacteria.
- Shop for cold and frozen foods last and take them immediately home to the refrigerator or freezer. Use ice chests in your car during transport, especially in the summer months or when running errands.
- Buy food only if it is in good condition. Frozen foods should be solid, refrigerated case food should be well-chilled, and canned goods should be free of dents and bulging lids. Point out any problems to the store manager.

When in your Kitchen

- Always wash your hands in hot soapy water before food preparation and after handling raw meat, poultry or fish.
- Keep your refrigerator's temperature as cold as possible without freezing your milk or produce (approximately 4°C). Keep your freezer's temperature cold enough to keep frozen food rock hard (approximately -18°C). If you are ever in doubt, temperatures can be checked with an appliance thermometer.
- After shopping, put any fresh meat, poultry, or fish, which won't be use within the next few days directly into the freezer.
- Thaw frozen food in the refrigerator or in a microwave followed by immediate cooking. ***Do not thaw food at room temperature on the counter***.
- Take great care to avoid dripping of raw meat, poultry, or fish juices onto or into other foods in the refrigerator. Use plates, platters or containers under them if necessary.
- Never put cooked food back on a plate/container which has had fresh juices on it. For example, when barbecuing take out an extra platter to put the grilled food on.
- Use non-porous plastic cutting boards for preparation and cutting of meat, poultry, and fish.
- Wash all cutting boards surfaces, platters, and containers which fresh meat, poultry, and fish have come in contact with, in hot, soapy water thoroughly before using for other foods.
- Avoid cross contamination by washing kitchen towels after contact with raw juices and by replacing sponges often. *Use paper towels wherever you can.* A good disinfectant for utensils and countertops is one tablespoon household bleach in few litres of water.

- When using eggs, cook them until firm. Don't use recipes calling for only partially cooked eggs. For example, raw cookie dough could be dangerous.

When using the microwave remember there can be cold spots, so stir and rotate food for thorough cooking.

11.11 THE MOST IMPORTANT POINT TO REMEMBER IS TO WASH YOUR HAND

Preferably with antibacterial soap for at least 20 seconds....

- ***before food preparation***
- ***after fresh meat, poultry, or fish handling and before you then touch other food, eat, or prepare baby bottles***
- ***after using the bathroom***
- ***after changing diapers***
- ***after helping toddlers in the bathroom***
- ***after cleaning the bathroom***
- ***after handling pets, cleaning litter boxes or dog runs***

PLEASE REMEMBER: Foodborne bacterial illness can be very contagious. This is called secondary transmission where a person gets ill not from ingesting the contaminated food but from coming in close contact with someone who has. Secondary transmission has been documented in the home, in day care centres, in preschools, in schools, in hospitals, and in senior citizen facilities. When someone you know has diarrhoeal illness, use extreme sanitary measures, to guard against the spread of the disease. The use of anti-diarrhoeal medication for treatment of foodborne bacterial diarrhoea is not recommended and in some cases can be harmful. If symptoms are severe, see your doctor. If food poisoning is suspected, call your local health department. Your prompt action could help prevent someone else from getting ill.

11.12 LET US SUM UP

In this unit, we attempted to familiarize you with certain outbreaks of bacteria which are responsible for food borne infections. We hope that you will be able to know the various bacteria which cause food borne infections. You will also be able to differentiate in the symptoms of the diseases caused and list the main reasons for the outbreak of the infections. This unit would also have helped you to know the information regarding the prevention of the outbreaks of the disease.

11.13 KEY WORDS

Food Infection : Food borne disease caused due to ingestion of large number of viable organisms which cause disease.

Zoonotic Diseases : Those diseases and infections which are naturally transmitted between vertebrate animals and man.

Salmonellosis	:	Food borne infection caused by *Salmonella gastroentritis*.
Enterotoxigenic *E. coli*	:	*E. coli* which produce toxins in the intestine.
Cholera	:	Food borne infection caused by *Vibrio cholarae*.
Shigellosis	:	Food borne infection caused by *Shigella sonnei*, *S. dysenteraei*.
Yersiniosis	:	Food borne infection caused by *Yersinia enterolytica*.
Listeriosis	:	Food borne infection caused by *Listeria monocytogenes*.

11.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. • Salmonella food infection is caused by *Salmonella gastroenteritis*.
   - Transmitted by fecal contamination of foods.
   - Incubation period 12-36 hours.
   - Symptoms: nausea, vomiting, diarrhoea, abdominal pain and green watery stools.
   - About 10^6-10^9 organisms must be ingested to cause infection.
   - *Salmonellosis* prevented by: prevention of contamination of food by Salmonella, avoiding intake of contaminated food and by destruction of organism at 66ºC for 12-15 min.

2. Prevention of Food borne infections:
   - Avoid consumption of contaminated foods and water
   - Eat properly cooked foods
   - Wash raw fruits and vegetables properly
   - Proper hygiene

Check Your Progress Exercise 2

1. • Bacillary dysentery is caused by *Shigella* sp. (*Shigella sonnei, S. dysenteraei).*
   - Incubation period is about 1 to 7 days.
   - Causes abdominal pain, cramps, inflammation of intestinal mucousa, diarrhoea, vomiting, nausea and fever.
   - In severe cases; intestinal bleeding, electrolytic imbalance, ulceration, kidney failure and jaundice.

2. • Campylobacteriosis incubation period: 2-5 days after ingestion of contaminated food.

- Symptoms: Diarrhoea containing blood, fever, abdominal pain, nausea, headache and muscle pain.
- Transmission of infection by raw chicken, raw milk and non-chlorinated water.

Check Your Progress Exercise 3

1. • Yersiniosis caused by the bacteria *Yersinia enterolytica*.
   • Causes severe abdominal pain, fever and diarrhoea.
2. • Listriosis caused by *Listeria monocytogenes* infection.
   • Transmitted by animal excretions (fecal matter) and secretions, infected vegetables, aerial contamination, sewage, sludge, polluted water, rivers and infected animal products like milk and milk products, meat, fish etc.

11.15 SOME USEFUL BOOKS

1. Ayers, J.C., Mundt, J.O., Sandine, W.E. (1980) Microbiology of Foods, W.H Freeman and Co., San Franscisco. pp708.
2. Frazier, W.C. and Westoff, D.C. (1988) Food Microbiology, Tata McGraw-Hill Publishing Co., New Delhi. pp 539.
3. Pelczar, M.J., Chan, E.C.S., Kreig, N.R. (1997) Microbiology, Tata McGraw-Hill Publishing Co Ltd, New Delhi. pp 918.

UNIT 12 CHEMICAL

Structure

12.0 OBJECTIVES

After studying this unit, you should be able to:

- know about different types of chemical preservatives; and
- define the essential chemical preservative limits for the various foods.

12.1 INTRODUCTION

In this unit we will make you aware about the characteristics of various chemical preservatives with special stress on antimicrobial food preservatives. We will also brief you about different chemical preservatives permitted in processed products along with maximum levels of antimicrobials permitted in foods. You will also learn about various factors which determine/ influence the action of chemical food preservatives.

12.1.1 Need for Food Preservation

Unless you grow all your food in your own garden and prepare all your meals from scratch, it's almost impossible to eat food without preservatives added by manufacturers during processing.

Food preservation is a method of preparing food so that it can be stored for future use. Because most foods remain edible for only a brief period of time, people since the earliest ages have experimented with methods for successful food preservation. Among the products of early food conservation were cheese and butter, raisins, pemmican, sausage, bacon, and grain. Scientific investigations pointed that food spoilage was mainly caused by microorganisms widely distributed in the environment. Therefore, food preservation depends on rendering conditions unfavourable for microbial growth

12.1.2 Techniques of Food Preservation

The techniques of food preservation can be separated into two groups:

- physical
- chemical

Physical methods of preservation rely on killing the microorganisms present, or at least stopping their growth for long enough to allow the food to be safely consumed. The physical methods include canning, freezing, drying, gamma irradiation, ultraviolet or high intensity white light, ultra high pressure and filtration.

Chemical food preservatives are substances which, under certain conditions, either delay the growth of microorganisms without necessarily destroying them. These are added in very low quantities and which do not alter the organoleptic and physico-chemical properties of the foods at or only very little. These work either as direct microbial poisons or by reducing the pH to a level of acidity that prevents the growth of microorganisms.

12.2 CHARACTERISTICS OF CHEMICAL PRESERVATIVES

The Food, Drug, and Cosmetic Act permit for the use of chemical preservatives in foods if the chemical is:

1. Generally recognized as safe (GRAS) for such use; or if a food additive is covered by food additive regulations prescribing conditions of safe use.
2. Not used in such a way as to conceal damage or inferiority or to make the food appear better or of greater value than it is.
3. Properly declared on the label of the food in which used.
4. It should be food grade.
5. It should perform its intended function.
6. It should be used in accordance with good manufacturing practices and, where applicable, in accord with existing food additive regulations.

According to rules, a food manufacturer must get approval from Government regulatory authorities before using a new preservative, or before using a previously approved preservative in a new way or in a different amount. In its petition for approval, the manufacturer must demonstrate that the preservative is safe for consumers, considering:

- the probable amount of the preservative that will be consumed with the food product, or the amount of any substance formed in or on the food resulting from use of the preservative
- the cumulative effect of the preservative in the diet
- the potential toxicity (including cancer-causing) of the preservative when ingested by humans or animals.

- A preservative may not be used to deceive a consumer by changing the food to make it appear other than it is. For example, preservatives that contain sulfites are prohibited on meats because they restore the red colour, giving meat a false appearance of freshness.
- The food additive regulations require the preservative to be of food grade and be prepared and handled as a food ingredient.
- The quantity added to food must not exceed the amount needed to achieve the manufacturer's intended effect.

Regulations about the use of nitrites demonstrate the scrutiny given to the use of additives. Nitrites, used in combination with salt, serve as antimicrobials in meat to inhibit the growth of bacterial spores that cause botulism, a deadly food-borne illness. Nitrites are also used as preservatives and for flavouring and fixing colour in a number of red meat, poultry, and fish products. Since the original approvals were granted for specific uses of sodium nitrite, safety concerns have arisen. Nitrite salts can react with certain amines (derivatives of ammonia) in food to produce nitrosamines, many of which are known to cause cancer. A food manufacturer wanting to use sodium nitrites must show that nitrosamines will not form in hazardous amounts in the product under the additive's intended conditions of use. For example, regulations specify that sodium nitrite, used as an antimicrobial against the formation of botulinum toxin in smoked fish, must be present in 100 to 200 parts per million. In addition, other antioxidants, such as sodium ascorbate or sodium erythorbate, may be added to inhibit the formation of nitrosamines.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are chemical preservatives?

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2. Name three important characteristics of chemical preservatives?

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3. Name important facts that a manufacturer must demonstrate to regulatory authorities for getting a new preservative formulation approved?

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12.3 CLASSIFICATION OF PRESERVATIVES

Preservatives can be categorized into following types:

1. Antimicrobials that inhibit growth of bacteria, yeasts, or molds.
2. Antioxidants that slow air oxidation of fats and lipids, which leads to rancidity.
3. Antienzymatic that blocks the natural ripening and enzymatic processes that continue to occur in foodstuffs after harvest.
4. Preservatives from natural products.
5. Traditional preservatives

We will discuss the first type of preservatives in detail but before that brief description of other types is given below for the sake of awareness.

12.3.1 Antioxidant Preservatives

As antioxidants, they keep foods from becoming rancid, browning, or developing black spots. Rancid foods may not make you sick, but they smell and taste bad. Antioxidants suppress the reaction that occurs when foods combine with oxygen in the presence of light, heat, and some metals. Antioxidants also minimize the damage to some essential amino acids--the building blocks of proteins--and the loss of some vitamins.

Antioxidant preservatives, such as butylated hydroxytoluene, butylated hydroxyanisole, *tert*-butylhydroquinone, and propyl gallate, stop the chemical breakdown of food that happens in the presence of oxygen. Unsaturated fatty acids in oils and lipids are particularly susceptible to autooxidation. In this process, a free radical initiates peroxide formation at fatty acid double bonds. The chain reaction propagates to other double bonds, and aldehyde, ketone, and acid-termination products eventually build up to create the rancid off-flavors characteristic of oils and fats gone bad. Antioxidant preservatives sop up the free radicals that help initiate and propagate these reactions.

12.3.2 Preservatives that Targets Enzymes

These are preservatives that target enzymes in the food itself that continue to metabolize after harvest. The enzyme phenolase, for example, goes to work as soon as an apple or potato is cut. It browns the exposed surface. Acids such as citric acid and ascorbic acid (vitamin C) inhibit phenolase by making the pH uncomfortably low for the enzyme. Metal-chelating agents such as EDTA (ethylenediamine tetraacetic acid) can remove the metal cofactors that many enzymes need. Chelators also make it difficult for bacterial and fungal enzymes to carry on.

12.3.3 Preservatives from Natural Products

Some of the newest antimicrobials have been found in microorganisms themselves as they form their own chemical defenses when competing with each other for space and nutrients. For example, nisin and natamycin, the cheese preservatives called bacteriocins – are harvested from microorganisms. In the U.S., nisin is used to inhibit outgrowth of *Clostridium botulinum* spores (the cause of botulism) and toxin formation in pasteurized process cheese spreads with fruits, vegetables or meats at levels not exceeding good manufacturing practice. Current good manufacturing practice in this case is the quantity of the ingredient that delivers a maximum of 250 p.p.m. of nisin in the finished product. Nisaplin-brand nisin is also approved for liquid egg products, dressings, and sauces. In other countries it is also used in fresh and recombined milk, fermented beverages like beer, canned foods, frozen desserts, and high moisture/reduced fat foods. Nisin is considered effective at controlling a wide range of gram-positive organisms including: *Listeria enterococcus*, *Bacillus sporothermodurans*, and *clostridium*. Used alone, it is not effective on gram-negative bacteria (like *E. coli*), yeasts, and molds. However, research suggests that it may be useful against some gram-negative bacteria when used in conjunction with other preservatives.

12.3.4 Traditional Chemical Food Preservatives

Traditional chemical food preservatives and their use in fruit and vegetable processing technologies are common salt and sugar.

Common salt used in brined vegetables. There is no limit for their use.

Sugars (sucrose, glucose, fructose and syrups): foods preserved by high sugar concentrations such as jellies, preserves, syrups, juice concentrates. It acts by interaction of sugar with other ingredients or processes such as drying and heating. There is no limit for their use.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name two anti-oxidant preservatives?

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2. How does ascorbic and inhibit phenolase enzyme?

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3. Name two preservatives of microbial origin?

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4. Is there any limit for traditional food preservatives?

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12.4 ANTIMICROBIAL PRESERVATIVES

Usually accepted chemical food preservatives are detailed in Table 12.1.

Table 12.1: Commonly used antimicrobial chemical food preservatives

Agent	Acceptable Daily intake (mg/Kg body weight)	Commonly used levels (%)	Typical usage
Sorbic acid Potassium sorbate	25	0.05-0.2	fruits; vegetables; pickled products; jams, jellies
Benzoic acid Sodium benzoate	5	0.03-0.2	Vegetable pickles; preserves; jams; jellies; semi-processed products
Propionic acid Sodium propionate	10	0.1-0.3	Bakery goods, cheese spread, fruits, vegetables
Methyl paraben Ethyl paraben Propyl paraben	10	0.05-0.1	Bakery goods, fruit products; pickles; sauces
Lactic acid	No limit	No limit	Fermented meat, dairy and vegetable products, sauces and dressings, drinks.
Citric acid	No limit	No limit	fruit juices; jams; other sugar preserves
Acetic acid	No limit	No limit	vegetable pickles; other vegetable sauces, chutney
Sodium nitrite	0.2	0.01-0.02	Meat products
Sulphur dioxide	0.7	0.005-0.2	fruit juices, dried / dehydrated fruits and vegetables, semi-processed products

12.4.1 Organic Acids and Esters

Sodium Benzoate and Benzoic Acid

Benzoic acid is the compound with the antimicrobial properties, and is found naturally in cranberries, prunes, greengage plums, cinnamon, ripe cloves and apples. Sodium benzoate produces benzoic acid once it is dissolved in water.

Sodium benzoate is the sodium salt of benzoic acid and is preferred over benzoic acid in many food applications because it is 180 times more soluble in water. There is a marked pH effect for this preservative: the lower the pH, the more effective it is. Sodium benzoate will only work if the food product has a pH below 4.5; that is, if the food is naturally acidic or has been acidified.

For example, at pH 3.0 you only need approximately 0.05% of the compound to achieve the same antimicrobial effect as pH 4.0 and 0.1% benzoate. Optimum functionality occurs when the pH is between 2.5 and 4.0.

Sodium benzoate is used in fruit products, jams, relishes, beverages, dressings, salads, pie and pastry fillings, icings, olives and sauerkraut, and is effective against yeasts, some bacteria (food borne pathogens but not spoilage bacteria) and some molds. Sodium benzoate is a white granular or crystalline powder, odorless, inexpensive (at the usage level) and should be stored in a cool, dry place in watertight containers, if possible. It should be used at low levels to avoid possible off-flavours in some products. The maximum level allowable by law is 0.1%.

Sorbates

This family of compounds are available as sorbic acid, potassium sorbate, sodium sorbate or calcium sorbate. Sorbic acid is the compound with the antimicrobial properties but its salts (sorbates) are used in many cases due to differences in solubility.

Potassium sorbate is the potassium salt of sorbic acid, and is much more soluble in water than the acid. It is a white crystalline powder, inexpensive (at the usage level), with basically no noticeable flavour at normal usage concentrations. In wine processing, sorbates are used to prevent refermentation. Maximum level allowable by law is 0.1%. It produces sorbic acid once it is dissolved in water and is the most widely used food preservative in the world. It is effective up to pH 6.5 but effectiveness increases as the pH decreases. It has about 74% of the antimicrobial activity of the sorbic acid, thus requiring higher concentrations to obtain the same results that pure sorbic acid provides. It is effective against yeasts, molds, and select bacteria, and is widely used at 0.025 to 0.10 % levels in cheese, dips, yogurt, sour cream, bread, cakes, pies and fillings, baking mixes, doughs, icings, fudges, toppings, beverages, margarine, salads, fermented and acidified vegetables, olives, fruit products, dressings, smoked and salted fish, confections and mayonnaise.

It is important to know that the addition of sodium benzoate and/or potassium sorbate to a food product will raise the pH by approximately 0.1 to 0.5 pH units depending on the amount, pH, and type of product. Additional adjustment of the pH might be needed to keep the pH at a safe level.

In many food products, sorbate and benzoate are used together to provide greater protection against a wider variety of microorganisms. This only makes sense if the pH of the product is below 4.5.

Propionic acid

Propionic acid occurs naturally in strawberries, apples, violet leaves, grains. It is produced during the fermentation of some cheeses such as Swiss cheese, in concentrations as high as 1%, thus inhibiting the growth of molds. The acid is effective against bread molds and the spores of the bacterium *Bacillus mesentericus*, which cause an inedible condition in baked goods called rope. It is an oily liquid, soluble in water, with a slight pungent, disagreeable, rancid odour. It is also corrosive and flammable, thus requiring special handling.

Propionic acid and its salts, sodium and calcium propionates, are approved in the United States as GRAS (Generally Recognized As Safe) substances for food use. Their antimicrobial action is directed to molds and rope bacteria, with almost no effect on yeast, thus making them an ideal choice for products that use commercial yeast as an ingredient.

Like other preservatives, propionates effectiveness is affected by the pH of the food, with 5.5 pH being the upper effective limit. They are used mainly as mold and rope inhibitors in bread; although they are also useful in cheese, non-alcoholic beverages, confections, fillings, frostings, fresh dough, pizza crust, puddings, gelatins, jams, jellies and some meat products.

The sodium and calcium salts are transparent and white crystals with a mild cheese like flavour. The sodium form is more soluble in water than the calcium salt. Sodium propionate is recommended in baked products that use baking powder and baking soda instead of yeast as the leavening agent, because the presence of calcium ions (if you were to use calcium propionate) disrupts the leavening process. Calcium propionate is preferred in baked foods that use yeast, such as breads and rolls, because the nutritional value is increased by the added calcium.

Typical usage level of propionic acid and propionates is 0.1 to 0.4 %. Federal regulations limit the maximum level for flour, white bread and rolls at 0.32% based on the weight of the flour; for whole wheat products at 0.38% based on the weight of the flour; and for cheese products at 0.3 %.

It is important to know that the addition of sodium and calcium propionate to a food product will raise the pH by approximately 0.1 to 0.5 pH units depending on the amount, pH and type of product. Additional adjustment of the pH might be needed to keep the pH at a safe level.

Parabens

The parabens are esters of para-hydroxibenzoic acid. The two most common esters are methyl and propyl parabens, which are approved for food use in the United States under the GRAS classification. The maximum concentration allowed is 0.1 %. They are most active against yeasts and molds.

Parabens are white powders with faint odour and fair solubility in water at room temperature. The solubility is greatly increased by heating the water to 71.1°C-82.2°C. Methyl paraben is more soluble in water but less effective against molds than propyl paraben. To balance these differences, mixtures of 2 to 3 parts of methyl paraben with 1 part propyl paraben are normally used.

Important advantages of parabens are their effectiveness at higher pH values, from 3 up to 8, and stability to high and low temperatures, even to steam sterilization. Despite these properties, parabens are not as widely used as other antimicrobial agents, probably due to higher cost and flavour objections. Applications include bakery products (formulated without yeast), beverages, flavour extracts, food colours, fruit products, jams, jellies, preserves (artificially sweetened), gelatin, marinated and smoked fish, pickles, salad dressings, syrups, wine and olives.

Lactic acid

This acid is the main product of many food fermentations; it is formed by microbial degradation of sugars in products such as sauerkraut and pickles. The acid produced in such fermentations decreases the pH to levels unfavourable for growth of spoilage organisms such as putrefactive anaerobes and butyric-acid-producing bacteria. Yeasts and molds that can grow at such pH levels can be controlled by the inclusion of other preservatives such as sorbate and benzoate.

Acetic acid

Acetic acid is a general preservative inhibiting many species of bacteria, yeasts and to a lesser extent molds. It is also a product of the lactic-acid fermentation, and its preservative action even at identical pH levels is greater than that of lactic acid. The main applications of vinegar (acetic acid) includes products such as pickles, sauces and ketchup.

12.4.2 Gaseous Chemical Food Preservatives

Sulphur dioxide and sulphites

Sulphur dioxide (SO_2) has been used for many centuries as a fumigant and especially as a wine preservative. It is a colourless, suffocating, pungent-smelling, non-flammable gas and is very soluble in cold water (85 g in 100 ml at 25°C).

Sulphur dioxide and its various sulphites when dissolved in water at low pH yield sulphurous acid, bisulphite and sulphite ions. The various sulphite salts contain 50-68% active sulphur dioxide. A pH dependent equilibrium is formed in water and the proportion of SO_2 ions increases with decreasing pH values. At pH values less than 4.0 the antimicrobial activity reaches its maximum.

Sulphur dioxide is used as a gas or in the form of its sulphite, bisulphite and metabisulphite salts which are powders. The gaseous form is produced either by burning Sulphur or by its release from the compressed liquefied form.

Metabisulphite are more stable to oxidation than bisulphites, which in turn show greater stability than sulphites.

Mode of action

Sulphites inhibit microbial growth through a number of actions. They react with the energy rich compound, adenosine triphosphate; inhibit some metabolic pathways; and block cellular transport systems. Other antimicrobials alter microbial membrane or cell wall permeability or destroy the genetic material. In addition to its antimicrobial action, sulphur dioxide inhibits degradation reactions in fruits. It keeps raisins and other dried fruits from losing their light colour by blocking both enzymatic browning and a nonenzymatic browning reaction between reducing sugars and amino acids called the Maillard reaction. The reaction darkens raisins, alters their flavour, and reduces essential amino acid levels.

Uses

Sulphites are used to prevent or reduce discolouration of light-coloured fruits and vegetables, such as dried apples and dehydrated potatoes. These are added to sun-dried tomatoes, dried apricots, dried sweet potatoes, balsamic vinegar, red wine vinegar, lemon juice, and Hawaiian coconut syrup. These are also commonly used to lengthen the life of fruit juices. They are also used in wine-making because they inhibit bacterial growth but do not interfere with the desired development of yeast. Sulphites are also used in other ways, such as for bleaching food starches and as preventives against rust and scale in boiler water used in making steam that will come in contact with food. Some sulphites are used in the production of cellophane for food packaging.

Precautions

FDA prohibits the use of sulphites in foods that are important sources of thiamin (vitamin B1), such as enriched flour, because sulphites destroy the nutrient. It causes severe allergic reactions, especially in asthmatics though, for the majority of the population, they are safe.

According to FDA sulphites used specifically as preservatives must be listed on the label, regardless of the amount in the finished product. Sulphites used in food processing but not serving as preservatives in the final food must be listed on the label if present at levels of 10 parts per million or higher.

According to FDA the use of sulphites on fruits and vegetables intended to be eaten raw is banned. These were used to maintain the colour and crispness of fresh produce.

Carbon dioxide (CO_2)

CO_2 is a colourless, odourless, non-combustible gas, acidic in odour and flavour. In commercial practice it is sold as a liquid under pressure (58 kg per cm^3) or solidified as dry ice.

Carbon dioxide is used as a solid (dry ice) in many countries as a means of low-temperature storage and transportation of food products. Beside keeping the temperature low, as it sublimes, the gaseous CO_2 inhibits growth of psychrotrophic microorganisms and prevents spoilage of the fruits and vegetables, etc.

It is used as a direct additive in the storage of fruits and vegetables. In the controlled/ modified environment storage of fruit and vegetables, the correct combination of O_2 and CO_2 delays respiration and ripening as well as retarding mold and yeast growth.

The final result is an extended storage of the products for transportation and for consumption during the off-season. The amount of CO_2 (5-10%) is determined by factors such as nature of product, variety, climate and extent of storage.

Chlorine

The various forms of chlorine constitute the most widely used chemical sanitizer in the food industry. These chlorine forms include chlorine (Cl_2), sodium hypochlorite ($NaOCl$), calcium hypochlorite ($Ca(OCl)_2$) and chlorine dioxide gas (ClO_2).These compounds are used as water adjuncts in processes such as product washing, transport, and cooling of heat-sterilised cans; in sanitising solutions for equipment surfaces, etc.

Important applications of chlorine and its compounds include disinfection of drinking water and sanitation of food processing equipment.

12.4.3 Nitrites and Nitrates

Nitrites and nitrates are used mainly among the packaged meats. Sodium nitrate is added to meats such as ham, bacon, hot dogs and smoked fish. Nitrates break down in the body to nitrites and this stops the growth of bacteria, especially the bacteria that cause botulism poisoning. They are the food industry's primary chemical defense against the bacterium *Clostridium botulinum*.

It also stabilizes the red colour in cured meat and stops it turning grey. Nitrates readily convert to nitrites, which then react with the protein myoglobin to form nitric oxide myoglobin. During cooking, this is converted to nitrosohemochrome, a stable, pink pigment. They also impart a pink, fresh hue to cured meat. This chemical stabilises the red colour of the meat and gives an appearance of fresh meat. That is why nitrites are a favourite preservative of meat processors even though its excess use is restricted in many countries.

Precaution

Nitrite salts can react with certain amines in food to produce nitrosamines, which are known to cause cancer. Addition of Sodium ascorbate or sodium erythorbate inhibits nitrosamine formation and reduces the problem of nitrosamines.

The use of nitrite and nitrate has decreased greatly because of refrigeration and restrictions on the amounts used. Even though nitrite and nitrate cause only a small risk, it is always better to have fresh meat and meat product.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name four important organic acids used as chemical preservatives?

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2. What precautions should be observed before using SO_2 as preservative?

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3. How does nitrates impart red colour to meat?

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12.5 GENERAL RULES FOR CHEMICAL PRESERVATION

- Chemical food preservatives have to be used only at a dosage level which is needed for a normal preservation and not more.
- "Reconditioning" of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended.
- The use of chemical preservatives MUST be strictly limited to those substances which are recognised as being without harmful effects on human beings' health and are accepted by national and international standards and legislation.

Factors which determine/ influence the action of chemical food preservatives

a) Factors related to micro-organisms:

As a general rule it is possible to take the following facts as a basis:

- Sulphur dioxide and its derivatives can be considered as an "universal" preservative as; they have an antiseptic action on bacteria as well as on yeasts and molds;
- Benzoic acid and its derivatives have a preservative action which is stronger against bacteria than on yeasts and molds;
- Sorbic acid acts on molds and certain yeast species; in higher dosage levels it acts also on bacteria, except lactic and acetic ones;
- The initial number of microorganisms in the treated product determines the efficiency of the chemical preservative.
- The efficiency is less if the product has been contaminated because of preliminary careless hygienic treatment or an incipient alteration. Therefore, with a low initial number of microorganisms in the product, the preservative dosage level could be reduced.

b) Factors related to the product:

- Chemical composition of the product.
- *pH value of the product:* the efficiency of the majority of chemical preservatives is higher at lower pH values, i.e. when the medium is more acidic.
- *Physical presentation and size which the product is sliced to:* the chemical preservative's dispersion in food has an impact on its absorption and diffusion through cell membranes on microorganisms and this determines the preservation effect. Therefore, the smaller the slicing of the product, the higher the preservative action. Preservative dispersion is slowed down by viscous foods (concentrated fruit juices, etc.)

c) Miscellaneous factors

- *Temperature:* chemical preservative dosage level will be established as a function of product temperature and characteristics of the micro-flora;
- *Time:* at preservative dosage levels in employed in industrial practice, the time period needed in order to obtain a "chemical sterilisation" is a few weeks for benzoic acid and shorter for sulphurous acid.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is general rule about the dosage level of chemical preservative?

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2. Name one universal preservative?

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3. How does particle size of product affect the efficiency of preservative?

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12.6 LET US SUM UP

In this unit you have learnt about the chemical preservatives. Herein we have discussed the characteristics of approved chemical preservatives. Various types of preservatives grouped according to their mode of action have been discussed. More stress has been laid on antimicrobial preservatives owing to their importance. Factor influencing the effectiveness of various preservatives have also been discussed. We hope that after reading this unit you will become more conscious about reading the label of processed product before consuming it.

12.7 KEY WORDS

Food Spoilage	:	Undesirable change in flavours, odours appearances or texture of food.
Preservation	:	Safeguarding
Preservative	:	Additive
Anti microbial	:	Which act against microorganisms.
Anti oxidant	:	Which removes the oxygen.
GRAS	:	Generally recognized as safe.

12.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   Chemical food preservatives are substances which, under certain conditions, either delay the growth of microorganisms without necessarily destroying them. These are added in very low quantities and which do not alter the organoleptic and physico-chemical properties of the foods at all or only very little.

2. Your answer should include the following points:

   i) It should have GRAS (Generally recognized as safe) status.

   ii) It should be properly declared on the label of the food in which used.

   iii) It should be used only at approved dosage level.

3. Your answer should include the following points:

   In its petition for approval, the manufacturer must demonstrate that the preservative is safe for consumers, considering:

   - the probable amount of the preservative that will be consumed with the food product, or the amount of any substance formed in or on the food resulting from use of the preservative
   - the cumulative effect of the preservative in the diet
   - the potential toxicity (including cancer-causing) of the preservative when ingested by humans or animals.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   The two important antioxidant preservatives are:

   - butylated hydroxytoluene
   - butylated hydroxyanisole

2. Your answer should include the following points:

   Ascorbic acid (vitamin C) inhibit phenolase by making the pH uncomfortably low for the enzyme.

3. Your answer should include the following points:

   - nisin
   - natamycin

4. Your answer should include the following point:

   There is no limit for traditional food preservatives like salt and sugar.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   The four important organic acids used as chemical preservatives are:

   - Benzoic Acid
   - Sorbic acid
   - Propionic acid
   - Acetic acid

2. Your answer should include the following points:

   1. Sulphites should not be used in foods that are important sources of thiamin (vitamin B1), such as enriched flour, because sulphites destroy the nutrient.
   2. It should not be consumed by asthmatic patients because it may cause severe allergic reactions.

3. Your answer should include the following points:

   Nitrates readily convert to nitrites, which then react with the protein myoglobin to form nitric oxide myoglobin. During cooking, this is converted to nitrosohemochrome, a stable, pink pigment. That is how they impart a pink, fresh colour to cured meat.

Check Your Progress Exercise 4

1. Your answer should include the following points:

   Chemical food preservatives have to be used only at a dosage level which is needed for a normal preservation and not more.

2. Your answer should include the following point:

   Potassium meta bisulphate

3. Your answer should include the following points:

   - The smaller is the slicing of the product, the higher is the preservative action.
   - Preservative dispersion is slowed down by viscous foods

12.9 SOME USEFUL BOOKS

1. Adams, M.R. and Moss, M.O. (2000) Food Microbiology. Royal Society of Chemistry, Cambridge, U.K.

2. Branen, L.A. and Davidson, P.M. (1983) Antimicrobials in Food. Marcel Dekker, New York.

3. Igoe, R.S and Hui, Y.H. (1996) Dictionary of Food Ingredients – 3rd ed. Chapman & Hall, New York.

4. Jay, J.M. (2000) Modern Food Microbiology, Van Nostrand Company, New York.

5. Lewis, R.J. (1989) Food Additives Handbook. Van Nostrand Reinhold, New York.

UNIT 13 MICROBIAL

Structure

13.0 OBJECTIVES

After studying this unit, you should be able to explain:

- fresh fruits and vegetables;
- canned and processed food products; and
- drinking water.

13.1 INTRODUCTION

In this unit we will make you aware about the types of micro flora present on the surface of fresh fruits and vegetables, the sources of these microorganisms and the characteristics of pathogenic microorganisms. We will also brief you about quality standards for drinking water and the human pathogen present in contaminated water. Canning is an established way of food preservation. You will learn about the history of canning, spoilage of canned products with special reference to *Clostridium botulinum*. After that we will brief you about the microbial limits for processed foods.

13.2 MICROBIOLOGICAL PROFILE OF HARVESTED FRUITS AND VEGETABLES

The consumption of fresh fruits and vegetables is increasing as consumers strive to eat healthy diets. Global trade in fruits and vegetables and changing horticultural practices have enabled this year-round abundance to be possible, as well as adding new varieties of fresh produce to the market. During the last few decades pre-prepared minimally processed fruits and vegetables have become popular among the consumers. These products include pre-washed pre-cut salads items, grated vegetables, prepared fruit salads, or fruit combinations. Most of these products are generally eaten raw without further processing. Some products are packed in modified atmospheres to provide extension of shelf life both in relation to the potential acceptable quality and safety of the product.

Since minimum processing is required for fresh and fresh-cut fruits and vegetables, which omits any effective microbial elimination step, results in food products that naturally would carry microorganisms, some of which may be potentially hazardous to human health.

13.2.1 Sources of Microorganisms on Fresh Fruits and Vegetables

Fruits and vegetables can become contaminated whilst growing in fields, or during harvest, handling, processing, distribution and use. However, there are certain factors, which contribute to the microbiological contamination of these products with pathogens. Table 13.1 lists the sources of pathogenic microorganisms on fresh produce and conditions that influence their survival and growth.

Contamination can arise as a consequence of treating soil with organic fertilizers such as manure and sewage sludge and from irrigation water. Manure, bio-solids and irrigation water should be of a quality that does not introduce pathogens to the treated commodity. The potential of organic farming to contaminate fruits and vegetables with pathogens has to be investigated. Harvesting at the appropriate time and storing the harvested products under controlled conditions will help to retard growth of post-harvest spoilage and pathogenic microorganisms. Humid and warm storage conditions encourage the growth of microbial contaminants. The use of additional post-harvest procedures could reduce the contamination level of fruits and vegetables. Washing with water of potable quality can reduce the microbial load. Although a wide range of different agents are available for disinfecting/ sanitizing fresh produce their efficacy is variable and none is able to ensure elimination of pathogens. Fruits and vegetables carry a natural non-pathogenic epiphytic micro flora. During growth, harvest, transportation and further processing and handling the produce can, however, be contaminated with pathogens from human or animal sources. The microbial composition of the different forms of organic fertilizer will vary depending on its origin and further treatment. The quality of the water used for irrigation and as a carrier for plant protection products, fertilizers and frost protection products has to be related to the potential risk it can cause at a later stage. Technologies for irrigation are important for the control of spreading microbiological hazards. The use of drip irrigation instead of flooding or spray irrigation should reduce waterborne contamination and aerosols. However, heavy rains and wind may provide other opportunities for the transfer of microorganisms from soil to plant surfaces.

Table 13.1: Sources of pathogenic microorganisms on fresh produce and conditions that influence their survival and growth

Pre-harvest
• Soil • Irrigation water • Green or inadequately composted manure • Air (dust) • Wild and domestic animals • Human handling • Water for other uses (for example, pesticides, foliar treatments, growth hormones)
Post-harvest
• Human handling (workers, consumers) • Harvesting equipment • Transport containers (field to packing shed) • Air (dust) • Wash and rinse water • Sorting, packing, cutting and further-processing equipment • Ice • Transport vehicles • Improper storage (temperature, physical environment) • Improper packaging (includes new packaging technologies) • Cross contamination (other foods in storage, preparation and display areas) • Improper handling after wholesale or retail purchase • Cooling water (for example, hydro cooling)

13.2.2 Factors affecting Type and Number of Microorganism on Fresh Fruits and Vegetables

Fruits and vegetables normally carry a non-pathogenic epiphytic micro flora. The majority of bacteria found on the surface of plants are usually Gram-negative and belong either to the *Pseudomonas* group or to the *Enterobacteriaceae*. Many of these organisms are normally non-pathogenic for humans. The numbers of bacteria present will vary depending on seasonal and climatic variation and may range from 10^4 to 10^8 per gram. The inner tissues of fruits and vegetables are usually regarded as sterile. However, bacteria can be present in low numbers as a result of the uptake of water through certain irrigation or washing procedures. If these waters are contaminated with human pathogens these may also be introduced. The survival or growth of contaminating microorganisms is affected by intrinsic, extrinsic and processing factors. Factors of importance are nutrient composition, pH, presence of scales and fibers, redox potential, temperature and gaseous atmosphere. Mechanical shredding, cutting and slicing of the produce open the plant surfaces to microbial attack. About two thirds of the spoilage of fruits and vegetables is caused by molds. Members of the genera *Penicillium*, *Aspergillus*, *Sclerotinia*, *Botrytis* and *Rhizopus* are commonly involved in this process. The spoilage is usually associated with cellulolytic or pectinolytic activity, which causes softening of tissues, and weakening of plant structures. These structures are important barriers to prevent growth in the products by contaminating microbes.

13.2.3 Human Pathogens Associated with Fresh Fruits and Vegetables

However, risk profile surveys on the microbiological contamination of fruits and vegetables eaten raw demonstrates, potential for a wide range of these products to become contaminated with microorganisms, including human pathogens. The range of microorganisms associated with outbreaks linked to fresh produce encompasses bacteria, viruses and parasites. Most of the reported outbreaks have been associated with bacterial contamination, particularly members of the *Enterobacteriaceae*. Of these, *Salmonella* and *Escherichia coli* O157 are of particular concern. Outbreaks of illness caused by bacteria, viruses and parasites have been linked epidemiologically to the consumption of a wide range of vegetables and, to a lesser extent fruits. Surveillance of vegetables has indicated that these foods can be contaminated with various bacterial pathogens, including *Salmonella*, *Shigella*, *E. coli* O157:H7, *Listeria monocytogenes* and *Campylobacter*. Table 13.2 shows the characteristics of some microbial pathogens that have been linked to outbreaks of fresh fruits and vegetable associated illness.

Table 13.2: Characteristics of some microbial pathogens that have been linked to outbreaks of produce associated illness

Microorganism	Typical Incubation Period	Symptoms	Infectious Dose (Number of cells)	Source
BACTERIA				
Clostridium botulinum	12 to 36 h	Nausea, vomiting, fatigue, dizziness, dryness of mouth and throat, muscle paralysis, difficulty in swallowing, double or blurred vision, drooping eyelids, and breathing difficulties	Intoxication growth and toxin production in food	Soil, lakes, streams, decaying vegetation, reptiles
Escherichia coli O157:H7	2 to 5 d	Bloody diarrhoea, abdominal pain. Can lead to hemolytic uremic syndrome and kidney failure especially in children and the elderly	10 to 1000	Animal feces, especially cattle, deer and human; cross contamination from raw meat
Salmonella spp.	18 to 72 h	Abdominal pain, diarrhoea, chills, fever, nausea, vomiting	10 to 100,000	Animal and human feces; cross contamination from raw

				meat, poultry, or eggs
Shigella spp.	1 to 3 d	Abdominal pain, diarrhoea, fever, vomiting	~10	Human feces
Listeria monocytogenes	1 d to 5 or more wk	Febrile gastroenteritis in healthy adults; may lead to spontaneous abortion or stillbirth in pregnant women; severe septicemia and meningitis in neonates and immuno-compromised adults; mortality may be 20 to 40%	Unknown dependent upon health of individual	Soil, food processing environ-ments
PARASITES				
Cryptosporidium spp.	1 to 12 d	Profuse watery diarrhoea, abdominal pain, anorexia, vomiting	~30	Animal and human feces
Cyclospora spp.	1 to 11 d	Watery diarrhoea, nausea, anorexia, abdominal cramps (duration 7 to 40 d)	Unknown, probably low	Others? specific environment al sources unknown at this time
VIRUSES				
Hepatitis A	25 to 30 d	Fever, malaise, anorexia, nausea, abdominal pain, jaundice, dark urine	10 to 50	Human feces and urine
Norwalk/ Norwalk-like virus	12 to 48 h	Vomiting diarrhoea, malaise, fever, nausea, abdominal cramps	Unknown, probably low	Human feces, vomitus

However, multiplication of the pathogen is also essential for causing any damage. Some microorganisms cause illness only when ingested in high numbers (for example, *Clostridium perfringens*), while in other cases, the infectious dose is thought to be dependent upon the susceptibility of the individual (most infectious agents). Illness due to *Staphylococcus aureus*, *Bacillus cereus*, or *Clostridium botulinum* is a result of the production of toxins in the food, and it is the toxins that are responsible (sometimes in the absence of viable cells) for symptoms of the disease. These toxins are only produced by multiplying cells. This requires favourable growth conditions.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the sources of microbial contamination on fresh fruits and vegetables?

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2. What are the factors that affect the survival and growth of microorganisms on fruits?

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3. Name few fungi responsible for spoilage of fresh fruits and vegetables?

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4. Name two bacteria associated with outbreaks linked to fresh fruits and vegetables?

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13.3 STANDARDS OF WATER FOR HUMAN CONSUMPTION

Clean water is one of the most important needs of our bodies. It is a sad fact that something as essential to life as clean drinking water can no longer be granted to us. According to research articles and news, most tap and well water now are not safe for drinking due to heavy industrial and environmental pollution. We have reached to a point that, all sources of our drinking water, including municipal water systems, wells, lakes, rivers, and even glaciers, contain some level of contamination.

13.3.1 Sources of Contaminants in Drinking Water

Several contaminants occur in nature that may present a health risk if they are found in drinking water. The various pollutant /contaminants are bacteria, viruses, uranium, radium, nitrate, arsenic, chromium and fluoride. Other sources of contamination are a result of human activity such as manufacturing or agriculture, or individual misuse. The following activities may cause harmful microorganisms and chemicals to enter the well water owner's water supply.

- Leakage from waste disposal, treatment, or storage sites.
- Discharges from factories, industrial sites, or sewage treatment facilities.
- Leaching from aerial or land application of pesticides and fertilizers on yards or fields.
- Accidental chemical spills.
- Leakage from underground storage tanks.

13.3.2 Contamination due to Harmful Microorganisms

The most common and widespread health risk associated with drinking water is microbial contamination, either directly or indirectly, by human or animal excreta and micro-organisms contained in faeces.

The pathogenic agents involved include bacteria, viruses and protozoa, which may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diarroea, dysentry, hepatitis or typhoid fever. Most of them are widely distributed through out the world. Fecal contamination of drinking water is only one of the several faeco-oral mechanisms by which they can be transmitted from one person to another, or in some cases, from animal to people. The human pathogens potentially transmitted in drinking water are Bacteria viz. Escherichia coli,Salmonella, Shigella, Vibrio cholera, Yersinia enterocolitica, Campylobacter jejuni; viruses viz, Adenoviruses, Enterovirus, Hepatitis A, Hepatitis E, Norwalk virus, Rotavirus, and small round viruses; The parasites, Giardia, Cryptosporidium, Entamoeba histolytica and Drancunculus. The removal of these agents from drinking water should be given top priority.

Apart from the above said **pathogens of high health significance**, there are some more organisms that are present in environment and **not normally regarded as pathogen, may caue disease opportunistically**. When such organisms are present in water they cause infection predominantly among people whose local or general defence mechanisms are impaired. Those most likely to be at risk include the very old, the very young and patients in the hospitals,e.g. those with burns or immunosuppressive therapy, and those suffering from acquired immunodeficiency syndrome(AIDS). Water used by such patients for drinking or bathing, if it contains excessive number of these agents, may produce a variety of infections involving the skin and mucous membrane of the eye, ear, nose and throat. *Pseudomonas, Flavobacterium, Acinetobacter, Klebsiella* and *Serratia* are examples of such opportunistic pathogens. *Legionella* infects the lung. These organisms while clearly of medical importance, acquire public health significance only under certain conditions. There removal from drinking water may therefore be given moderate priority.

13.3.3 Drinking Water Standards

Microorganisms, including pathogenic organisms, may enter water supplies at every stage of the collection and distribution cycle. Emphasis should be placed on the need for an active watershed protection program, including an emergency plan for responding to major pollution events such as spills or contamination. Major quality requirements for drinking water are listed in Table 13.3.

Table 13.3: Drinking water standards

Micro-organism	Requirement
Cryptosporidium	System must remove 99% of *Cryptosporidium*
Giardia lamblia	99.9% killed
Heterotrophic Plate count (HPC)	Not more than 500 colonies per ml.
Total Coliform	Must not be detectatable in any 100 ml sample. In case of large supplies where sufficient samples are examined must not be present in 95% of the samples taken through out any 12 months period.
Fecal Coliform or *E.coli*	No fecal coliform is allowed.
Turbidity	At no time can turbidity go above 5 NTU (Nephlometric turbidity unit)
Viruses	99.99% killed / inactivated

Let us know in brief about the above contaminants.

Coliform bacteria

These are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease. **Fecal Coliform and *E.Coli*** are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhoea, cramps, nausea, headaches, or other symptoms.

Turbidity has no health effects. However, turbidity can interfere with disinfection and provide a medium for microbial growth. Turbidity may indicate the presence of disease causing organisms. These organisms include bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhoea, and associated headaches.

Cryptosporidium is a parasite that enters lakes and rivers through sewage and animal waste. It causes cryptosporidiosis, a mild gastrointestinal disease. However, the disease can be severe or fatal for people with severely weakened immune systems.

Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhoea, vomiting, cramps).

Hence, it is important that our drinking water does not contain any concentration of microorganisms, parasites or any other substance which constitutes a potential human health risk and it meets the minimum requirements (microbiological and chemical parameters and those relating to radioactivity) laid down by the directives.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name some common diseases caused due to contaminated drinking water?

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2. Name various pollutant/Contaminants of water?

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3. List some important human pathogen transmitted by drinking water?

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4. Name some opportunist pathogens in drinking water?

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13.4 MICROBIOLOGY OF CANNED FOODS

Foods are processed for convenience and safety. Food processing involves procedures such as: drying, canning, freezing, and pasteurization. For example, drying is a process by which water is removed from the product, causing the product to become dehydrated. Since microorganisms need water to grow, without moisture, they can't flourish. Canning is a process where foods are put into a container and given a high heat treatment to make the product sterile. The process of canning, be it vegetables, meat, or seafood, makes food safe because all dangerous microorganisms are destroyed. The canning process was developed to preserve food safely and for long periods of time.

13.4.1 History of Canning

The canning process dates back to the late 18th century in France when the Emperor Napoleon Bonaparte, concerned about keeping his armies fed, offered a cash prize to whoever could develop a reliable method of food preservation. Nicholas Appert conceived the idea of preserving food in bottles, like wine. After 15 years of experimentation, he realized if food is sufficiently heated and sealed in an airtight container, it will not spoil. An Englishman, Peter Durand, took the process one step farther and developed a method of sealing food into unbreakable tin containers, which was perfected by Bryan Dorkin and John Hall, who set up the first commercial canning factory in England in 1813. As more and more of the world was explored, and as provisioning armies took on greater importance, the demand for canned foods grew. Thomas Kensett, who emigrated to the United States, established the first U.S. canning facility for oysters, meats, fruits and vegetables in New York in 1812. More than 50 years later, Louis Pasteur provided the explanation for canning's effectiveness when he was able to demonstrate that the growth of microorganisms is the cause of food spoilage.

13.4.2 Basic Principal of Canning

The basic principles of canning have not changed dramatically since Nicholas Appert and Peter Durand developed the process. Heat sufficient to destroy microorganisms is applied to foods packed into sealed or "airtight" containers. The canned foods are then heated under steam pressure at temperatures of 116-121°C. The amount of time needed for processing is different for each food, depending on the food's acidity, density and ability to transfer heat. For example, tomatoes require less time than green beans, while corn and pumpkin require far more time. Processing conditions are chosen to be the minimum needed to ensure that foods are commercially sterile, but retain the greatest flavour and nutrition.

13.4.3 Spoilage of Canned Products

Heated canned foods may undergo spoilage either due to chemical or biological reasons. The most common spoilage of canned foods is the hydrogen swells produced as a result of action of food acid with the metal can. Such spoilage occurs mostly due to imperfect tinning and lacquering of interior of the can used for canning acidic foods. Biological spoilage of canned foods by the microorganism may result either from the survival of the organisms after the heat treatment or leakage of the container permitting entrance of the microorganisms, Surviving organisms may be vegetative cells or spore formers depending upon the heat treatment. Acid foods are processed at a temperature around $100^{O}C$ which result in killing of all vegetative cells of bacteria yeast and molds.

13.4.4 *Clostridium botulinum* a Major Threat in Canned Products

Growth of the bacterium *Clostridium botulinum* in canned food may cause **botulism –** a deadly form of food poisoning. These bacteria exist either as spores or as vegetative cells. Botulism is an **intoxication** that is caused by the ingestion of a virulent nerve toxin produced by the growth of the gram positive, obligate anaerobe, spore-former ***Clostridium botulinum***. This bacterium appears to be a normal inhabitant of the soil, hence is ready contamination of most foods. The spores can survive harmlessly in soil and water for many years. When ideal conditions exist for growth, the spores produce vegetative cells which multiply rapidly and may produce a deadly toxin within 3 to 4 days of growth in an environment consisting of:

- a moist, low-acid food
- a temperature between 4°C and 49°C
- less than 2 percent oxygen

It is able to grow in **absence of oxygen** in a wide variety of foods and in so doing produces a **protein neural toxin**, two to three grams (an amount equivalent to the quantity of salt in the average salt shaker on your table) of which would be sufficient to kill human being. However, the organism will not grow in the presence of oxygen or nitrate salts and it does not produce the toxin at a pH below 4.7. Only one strain, which is found associated with marine organisms, is able to produce the toxin at refrigerator temperature. The toxin is destroyed by boiling it at 100°C for 10 to 15 min. However, the spore requires a temperature of 121°C for 15 min to kill it. The toxin acts by binding to nerve junctions and destroying the nerve. The symptoms, which occur usually within 12 to 36 hours, but which can take up to 8 days to appear, classically consist of double vision, dizziness, inability to speak, breathe or swallow. Death often occurs due to the inability to breath. The only treatment is the injection of *antitoxin* to the several varieties of the toxin. This treatment is only effective against free toxin, as once the toxin has bound to the nerves the damage is irreversible. **The entire canning process is built around ensuring that all spores of this bacterium contaminating any canned food are destroyed in the sterilization process.** Industry has a sterling record in that deaths from commercial-botulism are very rare. This is influenced by the fact that once a product is known to contain botulism toxin none of that product is ever again purchased by a customer. **The majority of botulism poisonings occur in HOME-CANNED FOODS** prepared by grandma or your favourite aunt. A rule of thumb is “READ THE CANNING DIRECTIONS” and if you think a food might contain the botulism toxin never tastes even the smallest drop of it!

Some interesting additional information about this disease is:

- Never feed **raw honey** to a child under the age of two because the botulism spores can grow in the immature gut and produce the toxin. This can not occur in the adult due to our gut micro flora which is absent in infants.

- The botulism toxin is being used to treat certain neurological conditions where nerves that shouldn't fire do. In these cases tiny quantities of the botulism toxin is injected into the nerve, which the toxin kills and cures the condition.

- Ducks and chickens often die from botulism poisoning by eating rotting material in which the bacterium has grown. However, vultures, which as you know, eat disgusting rotten, stinking carrion, are immune to the toxin through evolution.

Botulinum spores are on most fresh food surfaces because they grow only in the absence of air, they are harmless on fresh foods. Botulinum spores are very hard to destroy at boiling-water temperatures; the higher the canner temperature, the more easily they are destroyed. Therefore, all low-acid foods should be sterilized at temperatures of 115°C to 121°C, attainable with pressure canners operated at 10 to 15 PSIG. PSIG means pounds per square inch of pressure as measured by gauge. At temperatures of 115°C to 121°C, the time needed to destroy bacteria in low-acid canned food ranges from 20 to 100 minutes. The exact time depends on the kind of food being canned, the way it is packed into jars, and the size of jars. The time needed to safely process low-acid foods in boiling-water canner ranges from 7 to 11 hours; the time needed to process acid foods in boiling water varies from 5 to 85 minutes.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is Canning?

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2. Name the person who for the first time conceived the idea of canning?

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3. Name the factor important in deciding canning time?

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4. Why is *Closteridium botulinum* a major threat in canned products?

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13.5 MICROBIOLOGICAL STANDARDS FOR PROCESSED FOODS

By now you know that microbiological hazards are one of the biggest threats to food safety. With better understanding in microbiology and food safety, safety limits have been set for a range of pathogenic microorganisms in foods. This subunit presents the recommended microbiological guidelines for some ready-to-eat food. According to the Codex Alimentarius Commission of the United Nations, an international food standard setting authority, the functions of

microbiological guidelines include formulation of design requirements, indication of required and expected microbiological status of the food commodities, and the verification of efficacy of hygienic practice. These guidelines stipulate the safety limits of nine major food borne pathogens such as *Salmonella* species, *Listeria monocytogenes*, *E coli O157* and *Vibrio cholerae*, as well as providing a classification of microbiological quality of ready-to-eat food for reflecting the hygienic status of the food concerned.

13.5.1 Purpose of Microbiological Standards

Microbiological Guidelines are criteria indicating the microbiological condition of the food concerned so as to reflect its safety and quality. These standard lists the maximum permissible levels of food borne microorganisms that pose a risk to human health in nominated foods, or classes of foods. They can be introduced to the food industry to observe voluntarily or stipulated in legislation for compliance.

13.5.2 Sampling

The statistical validity of a microbiological examination increases with the number of field samples analysed. For regulatory purposes, **a minimum of 5 sample units** from a lot is generally specified for examination. The size of the samples taken should also be adequate to enable appropriate microbiological analyses to be undertaken. A minimum sample size of 100g or ml is commonly required. **A lot** is defined as a quantity of food or food units produced and handled under uniform conditions. This may be restricted to a food item produced from a particular production line or piece of equipment within a certain time period (not exceeding 24 hours).

13.5.3 Microbiological Assessment

There are three major components under microbiological assessment of any food.

Aerobic colony count is a count of viable bacteria based on counting of colonies grown in nutrient agar plate. This is commonly employed to indicate the sanitary quality of foods. The incubation condition of ACC used in this guideline is **30° C for 48 hours**.

Indicator organism Counts refers to the selected surrogate markers. The main objective of using bacteria as indicators is to reflect the hygienic quality of food. *E. coli* is commonly used as surrogate indicator. Its presence in food generally indicates direct or indirect fecal contamination. Substantial number of *E. coli* in food suggests a general lack of cleanliness in handling and improper storage. **Specific pathogens Counts** refer to bacteria that may cause food poisoning. Mechanisms involved may be toxins produced in food or intestinal infection. Nine specific bacterial pathogens are included in this set of guidelines. The symptoms of food poisoning vary from nausea and vomiting (e.g. caused by *S. aureus*), through diarrhoea and dehydration (*Salmonella* spp. and *Campylobacter* spp.) to paralysis and death in the rare cases of botulism. The infectious doses vary from less than 10 to more than 10^6 organisms.

13.5.4 Categories of Food based on Microbial Quality

For assessment of hygienic quality, food items are grouped into five categories taking into account the raw ingredients used, and the nature and degree of processing before sale. The microbiological assessment of ready-to-eat food on the above three components will lead to the classification of the food quality into one of the following four classes:

a) **Class A:** the microbiological status of the food sample is **satisfactory.**

b) **Class B:** the microbiological status of the food sample is **less than satisfactory but still acceptable for consumption.**

c) **Class C:** the microbiological status of the food sample is **unsatisfactory**. This may indicate a sub-optimal hygienic conditions and microbiological safety levels. Licensees of food premises should be advised to investigate and find out the causes and to adopt measures to improve the hygienic conditions. Taking of follow-up samples to verify the improvement may be required.

d) **Class D:** the microbiological status of the food sample is unacceptable. The food sample contains unacceptable levels of specific pathogens that is **potentially hazardous to the consumer**. In addition to giving advice to the licensee of the food premises as stated in (c) above, warning letters as well as other enforcement actions should be considered. Microbiological limits in respect of the above components are summarized in the table 13.4.

Table 13.4: Guideline levels for determining the microbiological quality of ready-to-eat foods

Criterions		**Microbiological Quality (CFU per gram)**			
		Class A Satisfactory	**Class B Marginal**	**Class C Unsatisfactory**	**Class D Potentially Hazardous**
Aerobic colony count (ACC)[$30^{O}C$/48 hr]					
Food Category	**1**	$<10^3$	10^3-$<10^4$	$\geq 10^4$	N/A
	2	$<10^4$	10^4-$<10^5$	$\geq 10^5$	N/A

(Food items detailed in Table 5)	**3**	$<10^5$	10^5-$<10^6$	$\geq 10^6$	N/A
	4	$<10^6$	10^6-$<10^7$	$\geq 10^7$	N/A
	5	N/A	N/A	N/A	N/A
Indicator organisms (Apply to all food categories)					
E.coli (Total)		<20	20 -< 100	≥100	N/A
Pathogens (Apply to all food categories)					
Campylobacter spp		not detected in 25g	N/A	N/A	Present in 25 g
Escherichia coli 0157		not detected in 25g	N/A	N/A	Present in 25 g
Listeria monocytogenes		not detected in 25g	N/A	N/A	Present in 25 g
Salmonella spp		not detected in 25g	N/A	N/A	Present in 25 g
Vibrio cholerae		not detected in 25g	N/A	N/A	Present in 25 g
Clostridium perfringens		<20	20<100	$100<10^3$	$\geq 10^3$
Staphylococcus aureus		<20	20<100	$100<10^4$	$\geq 10^4$
Vibrio parahaemolyticus		<20	20<100	$100<10^4$	$\geq 10^4$
Bacillus cereus		$<10^3$	10^3-$<10^4$	10^4-$<10^5$	$\geq 10^5$

N/A Not applicable

The desired microbiological quality of the some food samples is summarized in Table 13.5.

Table 13.5: Food category table for aerobic colony count assessment

Food group	Food item	Category
Meat	Beefburgers and kebabs	1
	Dim sum	2
	Pate (meat, seafood or vegetable)	3
	Poultry (unsliced)	2
	Preserved meat	4
	Salami and fermented meat products	5
	Sausages	2
	Smoked meat	5
	Siu-mei & lo-mei	3
	Sliced meat (ham and tongue) (cold)	4
	Sliced meat (beef, haslet, pork, poultry, etc.) (dried)	3
	Steak and kidney / meat pies	2
	Tripe and other offal	4
Seafood	Crustaceans	3
	Pickled fish	1
	Other fish (cooked)	3
	Oysters (raw)	5
	Seafood meals	3
	Shellfish (cooked)	4
	Smoked fish	4
Dessert	Cakes, pastries, slices and desserts – with dairy cream	3
	Cakes, pastries, slices and desserts – without dairy cream	2
	Cheesecake	5
	Mousse / dessert	1
	Tarts, flans and pies	2
	Trifle	3
Savoury	Bean curd	5
	Cheese-based bakery products	2
	Fermented foods	5
	Flan / quiche	2
	Dips	4
	Mayonnaise / dressings	2
	Samosa	2
	Satay	3
	Spring rolls	3
Vegetable	Coleslaw / salads (with or without meat)	3
	Fruit and vegetables (dried)	3
	Fruit and vegetables (fresh)	5
	Rice	3

	Vegetables and vegetable meals (cooked)	2
Dairy	Cheese Yoghurt	5 5
Ready-to-eat meals	Pasta / pizza Meals (others)	2 2
Sandwiches and filled rolls	With salad Without salad	4 3
Sushi & sashimi	Fish fillet and fish roe sashimi / sushi Sashimi other than fish fillet and fish roe	3 4

Controlling microbes

Control of microbes in processed products primarily depend upon good manufacturing practices and one of the most effective way to ensure this is by application of HACCP. HACCP stands for Hazard Analysis of Critical Control Point. HACCP is a preventive system for assuring production of safe food. It is a process that identifies food safety hazards associated with a product and process and strictly manages and monitors the Critical Control Points (CCP's) designed to control the hazard as a way of ensuring the process is in control and that the safest product possible is being produced. It requires establishment of hazard, identification of critical control points, effective monitoring follow up and evaluation. For a food processor it is necessary to know the microbial quality of the raw material, the processing environment, and the packaging component. This also requires validation of all processing stages designed to destroy both the pathogens and the spoilage agents and the efficacy of preservative system.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is codex Alimentarius?

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2. Why do we need microbial standards?

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3. How many sample units from a lot are generally specified for examination?

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4. What are the major components under microbiological assessment of any food?

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5. Define Aerobic colony count?

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6. What does the presence of indicator organism in food reflect?

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7. Name the specific pathogens to be observed for microbial assessment of any food?

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13.6 LET US SUM UP

In this unit you have learnt about the microbial quality limits for various foods (raw and processed). Herein we have discussed the sources of microorganisms on fresh fruits and vegetables and in drinking water. Various Food and water borne harmful microorganisms including indicator bacteria, viruses and pathogens have been discussed briefly. *Clostridium botulinum* is an important organism for canning point of view. Hence, it has been dealt in more detail. WE HOPE that after reading this unit you will become more conscious about the microbial quality of food that you are going to eat.

13.7 KEY WORDS

Spoilage microorganism	:	Microorganism which spoil the product by developing undesirable flavours, odours and changing food appearances or textures via microbial action.
Pathogenic	:	Microorganism which may infect plants, animals and man and make them sick.
Hazardous	:	Harmful
Epidemic	:	Out break of infectious disease
Gastroenteritis	:	Inflamatory change of lining of stomach caused by microorganism ingested with food and water.
Hepatitis	:	Virus Hepatitis A
Parasites	:	Life on, within or at the expense of other organisms.
Toxin	:	Poison
Intoxication	:	Toxin production

13.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following point:

   - Sources of microorganisms on fresh fruit are air, orchard soil, irrigation water, harvesting device, storing and packaging containers, handling personnel etc.

2. Your answer should include the following points:

- The survival or growth of contaminating microorganisms is affected by intrinsic, extrinsic and processing factors.
- Factors of importance are nutrient composition, pH, presence of scales and fibers, redox potential, temperature and gaseous atmosphere.
- Mechanical shredding, cutting and slicing of the produce open the plant surfaces to microbial attack.

3. Your answer should include the following point:

- Members of the genera *Penicillium*, *Aspergillus*, *Sclerotinia*, *Botrytis* and *Rhizopus* are commonly involved in spoilage of fresh fruits and vegetables.

4. Your answer should include the following points:

- Most of the reported outbreaks have been associated with bacterial contamination.
- Members of the *Enterobacteriaceae*. Of these, *Salmonella* and *Escherichia coli* O157 are of particular concern.

Check Your Progress Exercise 2

1. Your answer should include the following points:

- Gastroenteritis
- Diarroea
- Dysentry
- Hepatitis
- Typhoid fever

2. Your answer should include the following points:

- Microbes
- Radionuclide
- Inorganics
- Volatile organics
- Disinfectants
- Disinfection by products etc.

3. Your answer should include the following points:

- The human pathogens potentially transmitted in drinking water are Bacteria viz. *Escherichia coli,Salmonella, Shigella, Vibrio cholera, Yersinia enterocolitica, Campylobacter jejuni.*
- Viruses viz, Adenoviruses, Enterovirus, Hepatitis A, Hepatitis E, Norwalk virus, Rotavirus, and small round viruses
- Parasites viz. *Giardia*, *Cryptosporidium*, *Entamoeba histolytica* and *Drancunculus*.

4. Your answer should include the following points:

- *Pseudomonas*

- *Flavobacterium*
- *Acinetobacter*
- *Klebsiella*
- *Serratia*
- *Legionella*.

Check Your Progress Exercise 3

1. Your answer should include the following point:

   - Process where foods are put into a container and given a high heat treatment to make the product sterile.

2. Your answer should include the following point:

   - Nicholas Appert

3. Your answer should include the following points:

   - Food's acidity
   - Density
   - Ability to transfer heat.

4. Your answer should include the following point:

   - Growth of the bacterium *Clostridium botulinum* in canned food may cause **botulism –** a deadly form of food poisoning.

Check Your Progress Exercise 4

1. Your answer should include the following point:

   - Codex Alimentarius is an international food standard setting authority.

2. Your answer should include the following points:

   - Lists the maximum permissible levels of food borne micro-organisms that pose a risk to human health in nominated foods, or classes of foods.
   - Indicate the microbiological condition of the food concerned so as to reflect its safety and quality.

3. Your answer should include the following point:

   - Minimum of 5 sample units from a lot is generally specified for examination.

4. Your answer should include the following points:

   - Aerobic colony count
   - Indicator organism Counts
   - Specific pathogens Counts

5. Your answer should include the following points:

- Count of viable bacteria based on counting of colonies grown in nutrient agar plate.
- Commonly employed to indicate the sanitary quality of foods.

6. Your answer should include the following point:

   - The presence of indicator organisms in food reflect the hygienic quality of food.

7. Your answer should include the following points:

   - *Campylobacter* spp.
   - *Escherichia coli* 0157
   - *Listeria monocytogenes*
   - Salmonella spp
   - *Vibrio cholerae*
   - *Clostridium perfringens*
   - *Staphylococcus aureus*
   - *Vibrio parahaemolyticus*
   - *Bacillus cereus*

13.9 SOME USEFUL BOOKS

1. Adams, M.R. and Moss, M.O. (2000) Food Microbiology. Royal Society of Chemistry, Cambridge, U.K.
2. Jay, J.M. (2000) Modern Food Microbiology, Van Nostrand Company, New York.

EXPERIMENT 1 PREPARATION OF MEDIA

Structure

1.1 INTRODUCTION

Microorganisms require certain basic nutrients and physical factors for the sustenance of life as do all other living organisms. However, their particular requirements may vary greatly. Nutritional needs of microbial cells are supplied in the laboratory through a variety of media to detect their presence. Microbiological media for the evaluation of spoilage and detection of bacteria, yeasts and molds in foods are mentioned in this chapter.

Objectives

After studying and performing this experiment, you should be able to:

- learn that microorganisms are ubiquitous and in nature, they do not segregate themselves by species but exist a mixture of many other cell types; and
- learn to make different media which are suitable for a particular genera of microorganisms to produce their discrete colonies.

1.2 EXPERIMENT

1.2.1 Principle

Many special purpose media are needed to facilitate recognition, enumeration and isolation of different types of microorganisms. To meet these needs, the microbiologists has developed numerous media which on the basis of their function may be classified as follows:

A) Selective media

These media provide nutrients that enhance the growth and predominance of a particular type of bacterium and do not enhance (and may even inhibit) other types of organisms that may be present. For instance, a medium in which cellulose is the only carbon source, will specifically select for, or enrich the growth of cellulose-utilizing organisms when it is inoculated with a soil sample containing many kinds of bacteria.

B) Differential media

Certain reagents or supplements, when incorporated into culture media, may allow differentiation of various kinds of microorganisms. For example, if a mixture of bacteria is inoculated on to a blood containing agar medium (blood agar) some of the bacteria may hemolyze (destroy) the red blood cells, others do not. Thus one can distinguish between hemolytic and non-hemolytic bacteria on the same media.

1.2.2 Requirements (Equipment/Machinery/Instrument/Chemicals/ Material)

- Autoclave (Portable)
- Balance
- Heating mantle/ water bath
- pH meter
- Laminar air flow
- Stirrer
- Pipettes
- Distilled water
- Media (nutrient agar, potato dextrose agar, violet red bile agar, plate count agar)
- Test tubes
- Beakers
- Cotton plugs
- pH paper
- Measuring cylinder

1.2.3 Procedure

The preparation of microbiological media usually involves the following steps:

1. Carefully weigh the proper amount of the dehydrated base medium or the correct proportion of constituent ingredients and dissolve in appropriate volume of distilled water and heat. Composition of the media is as given in Annexure-1.

2. Determine the pH of the medium, and adjust if necessary with dilute acid or alkali.

3. If a solid medium is desired, add agar (1.5-2%) and boil the medium to dissolve the agar.

4. Distribute the medium into tubes or flasks. The amount of medium distributed per container should be limited so that no point within the volume of the medium is more than 2.5 cm from the top surface of the container.

5. Autoclave at 121°C for 15 minutes. Some media (or specific ingredients) that are heat labile are sterilized by filtration.

1.2.4 Observations

Observe the pH using the pH meter or colour indicator solutions. At the next laboratory period observe for any contamination to ensure proper sterilization. Discard any contaminated flasks and wash them in disinfectant solution.

1.2.5 Results

After performing this experiment you will observe that suitable media for growth of bacteria is nutrient agar (pH 6.8-7.0) or plate count agar (pH 7.0), whereas for yeasts and moulds it is potato dextrose agar (pH 5.6) and malt agar (pH 5.4).

1.3 PRECAUTIONS

- Adjust the pH of the media accurately, to provide favourable condition of growth for the microorganisms. pH of the medium may change during sterilization and because of possible browning reactions, it is important not to exceed the recommended time and temperature.
- Prepare medium in such quantities that if stored, it will be used before loss of moisture through evaporation that becomes evident.
- To prevent contamination and excess evaporation of water from a medium in flask and tubes during storage, optionally fit aluminium foil or plastic with loose rubber bands before autoclaving in order to allow air to escape and to prevent the container from bursting.
- Avoid over loading autoclaves so that the rate of air exhaust and heating is not appreciably delayed. The autoclave should reach 121°C (15 psi) slowly but within 10 min. after starting the air exhaust operation.
- Flask or test tubes should be plugged with cotton or capped with paper.
- After sterilization gradually reduce the pressure within the autoclave (using no less than 15min) since liquids may be at a temperature above their boiling point at atmospheric pressure. If the pressure is lowered too rapidly, liquids may boil over and come out from the container.
- Used plates, pipettes, tubes etc. should be routinely decontaminated by autoclaving for 30 minute at 121°C.
- Media should be stored at 2-8°C in a dry, dust free area and should not be exposed to direct sunlight.

EXPERIMENT 2 MICROSCOPIC STAINING TECHNIQUES

Structure

2.1 INTRODUCTION

Visualization of microorganisms in the living state is most difficult, not only because they are minute but also because they are transparent and practically colourless when suspended in an aqueous medium. To study their properties and to differentiate microorganism into specific groups for diagnostic purposes, biological stains and staining procedures in conjunction with light microscopy have become major tools in microbiology. Chemically a stain may be defined as an organic compound containing a benzene ring, a chromophore (chemical group that imparts colour to benzene), and an auxochrome (chemical compound that helps in binding to cells).

Objectives

After studying and performing this experiment, you should be able to:

- learn the practical and theoretical basis of chemical staining;
- describe manipulative technique of smear preparation;
- explain procedures for simple staining and negative staining; and
- perform differential staining procedures such as the Gram's staining, acid fast staining and spore staining.

2.2 EXPERIMENT

2.2.1 Principle

Staining by various dyes provides contrast between microorganisms and their background, permitting differentiation among various morphological types and internal structure such as cell wall, vacuoles or nuclear bodies. It also enables the microbiologist to use higher magnifications.

Numerous staining techniques are available for visualization, differentiation and separation of bacteria in terms of morphological characteristics and cellular structures. A summary of commonly used procedures and their purpose is outlined in Figure 2.1.

- **Types of staining techniques**
  - **Simple Staining** Use of single stain
    - For visualization of morphological shape (cocci, bacilli and spirilli) and arrangement (chains, clusters, pairs and tetrads)
  - **Differential staining** Use of two Contrasting stains
    - Separation into groups
      - Gram's Stain
      - Acid-fast stain
    - Visualization of structures
      - Flagella stain
      - Capsule stain
      - Spore stain
      - Nuclear stain

Figure 1: Staining techniques

2.2.2 Requirements (Equipment /Machinery/Instrument and Chemicals/ Material)

- Bunsen Burner
- Microscope
- Test tube shaker
- Inoculating needle
- Cover slips
- Glass slides
- Sterilized test tubes
- Wash bottles
- Microbial cultures
- Distilled water
- Stains
- Immersion oil
- Tissue paper

2.2.3 Procedure

Preparation and fixation of bacteria for staining

Prior to staining, you must "fix" the material to be observed that is make it stick to the glass slide upon which is to be stained. If a preparation is not fixed, the film of cells will wash off during the staining procedure. Purpose of fixation is also to kill the microorganism and coagulate the protoplasm of the cell so as to fix it on glass surface (Figure 2.2).

The fixing technique, although not difficult, requires adequate care in its preparation. Follow these basic rules meticulously:

1. ***Preparation of glass slides:*** Clean slides are essential for preparation of microbial smears. Grease or oil from fingers on slides must be removed by washing the slides with soap and water, followed by a water rinse. After cleaning dry the slides and place them on laboratory towels until ready for use.

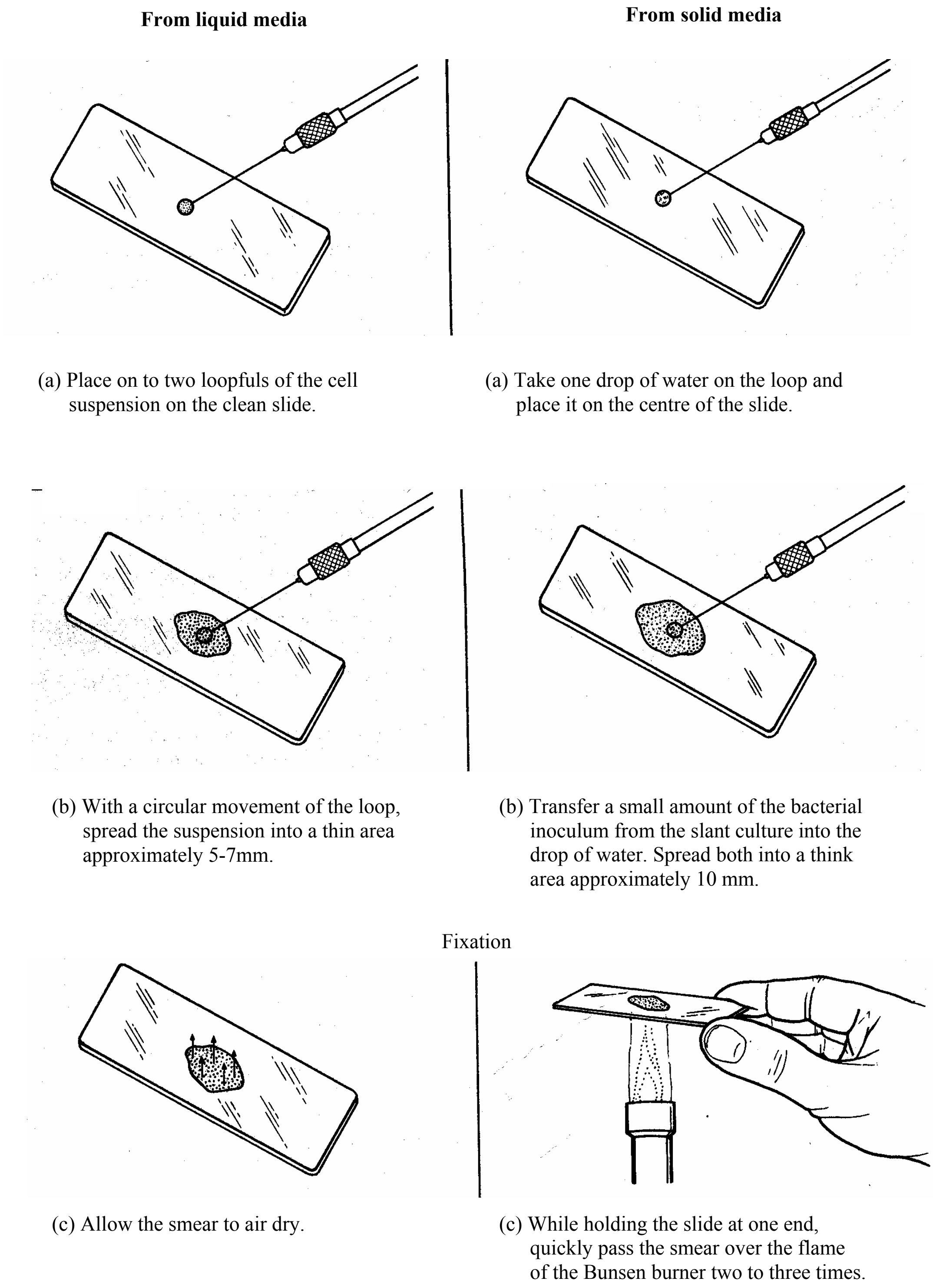


Figure 2.2: Bacterial smear preparation

2. ***Preparation of smear:*** Avoidance of thick, dense smears is absolutely essential. A good smear is one that, when dried, appears as a thin whitish layer or film. Those made from broth cultures or cultures from a solid medium require variations in technique.

   - *Broth cultures:* One or two loopful of suspended cells should be applied directly to the glass slide with a sterile inoculating loop and spread evenly over a small area.

   - *Cultures from a solid media:* Organisms cultured in a solid medium produce thick, dense surface growth and are not amenable to direct transfer to the glass slide. These cultures must be diluted by placing a loopful of water on the slide in which the cells will then be emulsified. Suspension is accomplished by spreading the cells in a circular motion in the drop of water with the needle tip. At this point, the smear must be allowed to dry completely. **Do not blow or wave it in the air.**

3. ***Heat fixation:*** Unless fixed on the glass slide, the bacterial smear will wash away during the staining procedure. This is avoided by heat fixation, during which the bacterial proteins are coagulated and fixed to the glass surface. Heat fixation is performed by the rapid passage of the air-dried smear two or three times over the flame of the Bunsen burner.

Staining with basic dyes

Herein, the bacterial smear is stained with a single basic stain. The bacterial nucleic acid and certain cell wall components carry a negative charge that strongly attract and bind to the cationic (negatively charged) chromogen. The purpose of simple staining is to elucidate the morphology and arrangement of bacteria.

The most commonly used basic stains are methylene blue, crystal violet and carbol fuchsin. Note that exposure time for staining cells to these dyes differs for each of these stains; carbol fuchsin requires 15-30 seconds, crystal violet 20-60 seconds and methylene blue 1-2 minutes for fresh cultures. For old cultures more time is required for staining.

General staining

Procedure for staining with different dyes:

1. Prepare bacterial smear of the organisms. Note: All smears must be heat fixed prior to staining.
2. Flood the smear with any one of the stains, using the appropriate exposure time.
3. Wash the stained preparation with tap water to remove excess stain. During this step, hold the slide parallel to the stream of water; in this way you can reduce the loss of organisms from the preparation.
4. Dry the slide using blotting paper.
5. Examine the stained preparation under the oil-immersion objective of the microscope.

Observe closely for significant difference in cell size, shape and arrangements.

Negative or indirect staining

1. Place a small drop of nigrosin close to one end of a clean slide.
2. Using sterile technique, place a loopful of inoculum from the mixed culture in the drop of nigrosin and mix.
3. With the edge of the second slide held at above 30° angle and placed in front of the bacterial surface, push the mixture to from a thin smear.
4. Air dry. Do not heat fixed slide.
5. Examine the slide under oil-immersion objective of the microscope.

Differential staining

Gram's stain

1. Prepare smear of the bacterial culture. Air-dry and fix these preparations with heat.
2. Flood smear with crystal violet and let stained for 30 seconds.
3. Rinse with water.
4. Cover the film with Gram's Iodine instantly and let stained for 1 min.
5. Wash with tap water.
6. Decolorize with 95% alcohol. For a thin smear, 10-20 second is long enough.
   Caution: Do not over-decolorize. Add reagent drop by drop until crystal violet fails to wash from smear.
7. Rinse with water.
8. Counter stain with safranine for 20-30 seconds.
9. Rinse with water and blot dry.
10. Examine under the oil-immersion objective.

Table 1: Steps in the gram's stain

Step	Procedure	Results	
		Gram +	Gram -
Initial Stain	Crystal Stain for 30 seconds	Stains purple	Stains purple
Mordant	Iodine for 30 seconds	Remains purple	Remains purple
Decolourization	95% ethanol for 10-20 seconds	Remains purple	Becomes colourless
Counterstain	Safranine for 20-30 seconds	Remains purple	Stains pink

Acid fast stain

1. Prepare a smear of bacterial culture.
2. Allow to air dry and heat fix in usual manner.
3. Flood smear with carbol fuchsin and place on a warm hot plate, allowing the preparation to steam for 5 minutes. **Caution**: Do not allow stain to evaporate, replenish stain as needed. Also prevent stain from boiling by adjusting the hot plate to a proper temperature.
4. Wash with tap water. Heated slides must be cooled prior to washing.
5. Decolorize with acidic alcohol (95% ethyl alcohol containing 2.5% HNO_3) for 10-30 seconds, a carbol fuchsin fails to wash from smear.
6. Wash with water.

7. Counter stain with methylene blue for 2 min.
8. Wash smear with tap water and blot dry.
9. Examine under the oil immersion objective.

Structural stain

Endospore stain

1. Prepare smear, air dry and fix with heat.
2. Flood smear with malachite green and place on a warm hot plate, allowing the preparation to steam for 2-3 minute.
   Caution: Do not allow stain to evaporate; replenish stain as needed. Prevent the stain from boiling by adjusting the hot plate at a proper temperature.
3. Cool slide and wash with water.
4. Counter stain with safranine for 30 min.
5. Wash with water and blot dry.
6. Examine under oil immersion objective.

2.2.4 Observations

In the space provided:

1. Draw a representative field for each organism
2. Describe the morphology of the organism with reference to their shape (bacilli, cocci, spirilli) and arrangements (chains, clusters, pairs)

Stain	Methylene blue	Gram Stain	Carbol Fuschin
Drawing of a representative field			
Cell morphology			
Arrangement			
Cell colour			

2.2.5 Results

Staining the microorganisms makes them contrast in colour with their surroundings so that they are more readily visible. Certain stains can also be used to identify certain structures of the cell which would otherwise be unseen.

2.3 PRECAUTIONS

- Clean, dry glass slide must be taken to prepare a smear.
- Thick dense smears should be avoided.
- The smear should be properly heat fixed on the slide to avoid its washing off during staining procedure.
- Do not heat fix in case of negative staining.
- Do not over decolorize in case of Gram's staining.
- Do not allow stain to evaporate while acid staining technique. Replenish stain as needed.

EXPERIMENT 3 CULTURING AND IDENTIFICATION OF MICROORGANISMS

Structure

3.1 INTRODUCTION

Microorganisms are ubiquitous. They are found in soil, air, water, food, sewage and body surfaces. In short, every area of our environment is replete with them. When grown on a variety of media, microorganisms will exhibit differences in the microscopic appearance of their growth. These differences, called cultural characteristics, are used as basis for separating microorganisms into taxonomic groups. The cultural characteristics for all non-microorganisms are contained in Bergy's Manual of Systemic Bacteriology with their morphological characteristics.

Objectives

After studying and performing this experiment, you should be able to:

- differentiate microorganisms into bacteria, yeasts and moulds; and
- know the different forms / shapes of microorganisms.

3.2 EXPERIMENT

3.2.1 Principle

The microorganisms can be divided into bacteria, yeasts and moulds on basis of the difference in their morphological, cultural and physiological characteristics.

Bacteria

Among the major characteristics of bacterial cells are their size, shape, structure and arrangement. These characteristics constitute the morphology of the cell. Bacteria are very small, most being approximately 0.5 to 1.0 micrometers in diameter. They are unicellular, have cell wall and cytoplasm but the nucleous is not well developed. The shape of a bacterium is governed by its rigid cell wall. Typical bacterial cells are spherical (cocci), straight rods (bacilli) or rods that are helically covered (spirilla).

Different patterns for arrangement for identification purposes are monococci, diplococci, streptococci, tetrads, staphylococci and sarcinae (Figure 3.1). Cocci generally reproduce by binary fission. Rod shaped bacteria may be sporulating type like *Bacillus* species and *Clostridium* species which produce endospores or they are non-sporulating like *Lactobacillus* species (Figure 3.2). Bacteria may be both motile (having flagella) or non-motile (no flagella).

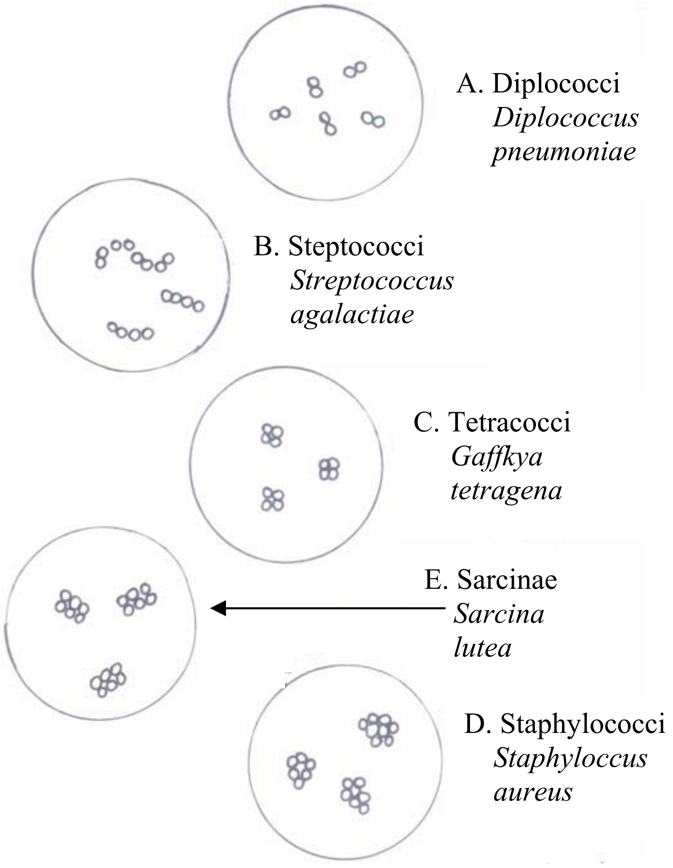


Figure 3.1: Characteristic arrangements of cocci

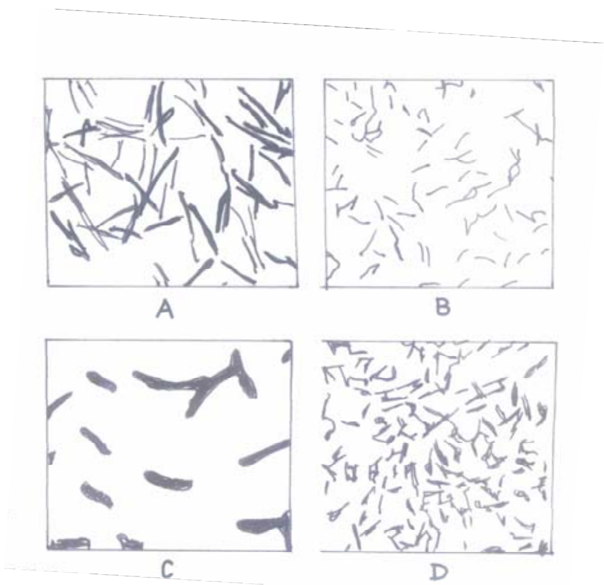


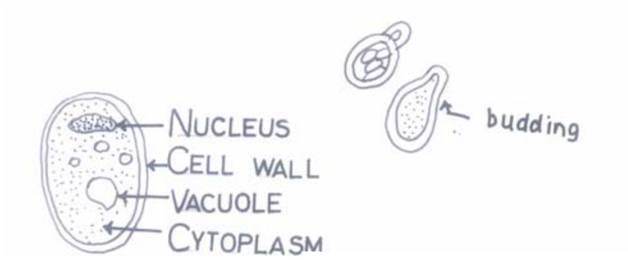
Figure 3.2: Types of rod-shaped bacteria. A) *Clostridium sporogenes*; B) *Pseudomonas sp.*; C) *Bacillus megaterium*; and D) *Salmonella typhi*

Fungi

Fungi is a group of eukaryotic organisms. They comprise of yeasts and moulds. Whereas moulds are filamentous and multicellular, yeasts are unicellular.

Yeasts

In general yeast cells are larger than most bacteria. Yeasts vary considerably in size ranging from 1-5 micrometer in width and from 5-30 micrometer in length. They are commonly egg-shaped, but some are elongated and some spherical. Yeasts lack flagella and other means of locomotion (Figure 3.3).



Saccharomyces sp. (a common bread yeast)

Figure 3.3: Yeast cell

Moulds

The thallus of moulds consist essentially of two parts: the mycelium and the spores. The mycelium is a complex of several filaments called hyphae. Filaments are made up of cells arranged end to end, branched and intertwined. Cells are like cells of higher plants in that they have visible nuclei, cell wall of varying thickness and cytoplasm. Mycelia in some fungi are divided into individual cells separated by cross walls and each cell containing a nucleus (Figure 3.4 and 3.5).

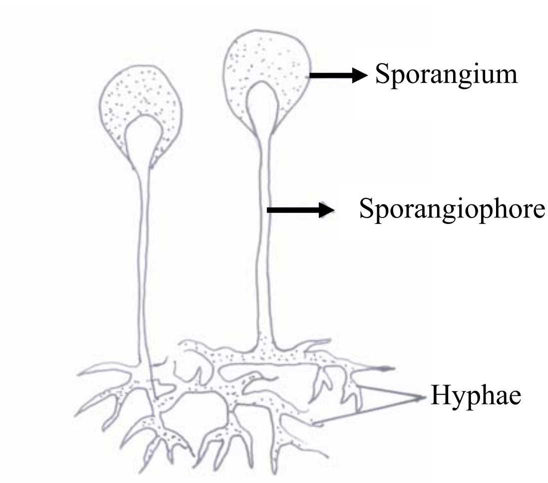


Figure 3.4: *Mucor* sp.

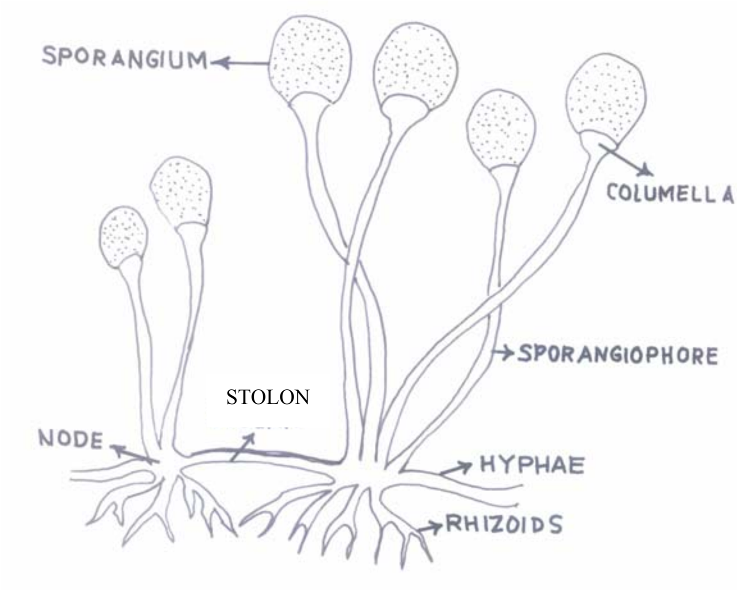


Figure 3.5: ***Rhizopus*** **sp.**

3.2.2 Requirements (Equipment/ Machinery/ Instrument and Chemicals/ Material)

- Compound microscope
- Bunsen burner
- Immersion oil
- Glass slides
- Inoculating needle
- Cover slips
- Tissue paper
- Microbial culture
- Distilled water

3.2.3 Procedure

1. Prepare the required media (broth or agar) for culturing the microorganisms
2. Place a small amount of media into test tubes, plug and sterilize them in an autoclave.
3. In case of solid media tubes, cool them in an incline position (slants)
4. When the medium is cold and solid, inoculate the surface of the medium using pre-sterilized needle. Move the needle gently on the agar surface in a snakelike motion from the butt to the top. In case of broth tubes, inoculate in the liquid media
5. Incubate both culture tubes at 30°C for few days.
6. In case of solid media, scoop out the mass of surface growth in which organism grows and put on clean, dry slide. From liquid broth, place a drop of culture on slide.
7. Observe under microscope.

3.2.4 Observations

In the chart provided:

1. Draw several cells from a typical microscopic field as viewed under each magnification.
2. Give the total magnification for each objective.
3. Observe spores or conidia and their arrangement.

	Bacteria	Yeast	Mould
Drawing of a representative field			
Magnification	---------------------	---------------------	--------------------

3.2.5 Results

Different types of spoilage have been encountered caused by various microorganisms. The type of microorganism proliferating depends on the composition of the material. The different spoilage microorganisms include bacteria, yeasts and moulds that can be observed and identified under a microscope by studying the morphological characteristics. These organisms vary in size, shape, colour, growth habit and mode of reproduction.

3.3 PRECAUTIONS

1. Use clean glass slides for smear preparation.
2. Thick, dense smears should be avoided.
3. Sterilize the inoculating needle before inoculation to avoid contamination.
4. The agar tubes should be properly sterilized.
5. Do not place the cotton plugs on ground during experiment.
6. Carefully view the characteristics of the microorganisms so as to differentiate them correctly.

EXPERIMENT 4 ASEPTIC CULTURE TECHNIQUE

Structure

4.1 INTRODUCTION

In previous experiments you learned that microorganisms thrive pretty much everywhere. It is far too easy to contaminate your lab cultures and experiments with stray microorganisms from the air, the countertop, or your tools. It is also possible to expose your surroundings or yourself to a possible pathogen. In this lab exercise, you will learn to transfer microbiological cultures from one medium to a second sterile medium without contamination of the culture, sterile medium, or the surroundings.

Objectives

After studying and performing this experiment, you should be able to:

- know how to handle microorganisms, tubed media, plated media, and inoculating tools such as loops, needles, or swabs etc.;
- learn how to transfer bacteria from test tubes or broth and agar; and
- learn how to transfer bacteria from Petri plates.

4.2 EXPERIMENT

4.2.1 Principle

Aseptic technique is a method that prevents the introduction of unwanted organisms into an environment. In order to protect sterile broth, media, plates, slants etc. from contamination we must practice aseptic i.e. sterile techniques to protect our material from contamination. By using aseptic technique only sterile surface touches other sterile surface and exposure to the non sterile environment is minimized.

Though, observing aseptic technique is the most important instruction for any microbiology experiment, some common circumstances will be discussed in this practical to make you aware of aseptic techniques.

Specific Aseptic Techniques

A) Sterilization of inoculation loop

The inoculation loop is sterilized by passing it at an angle through the flame of a gas burner until the entire length of the wire becomes orange or red hot. In this way all contaminants on the wire are incinerated. Never lay the loop down once it is sterilized or it may again become contaminated. Allow the loop to cool a few seconds to avoid killing the inoculum.

B) Transferring bacteria from broth culture to fresh broth

Requirements

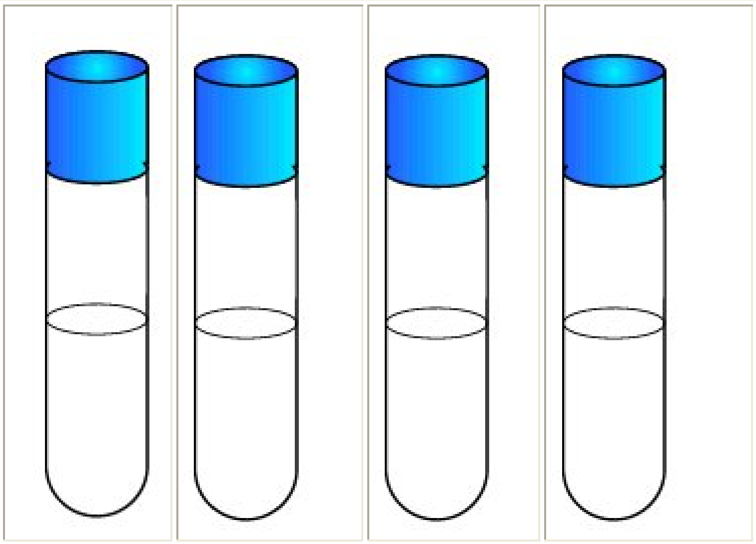
- Bunsen burner.
- Inoculation needle.
- Trypticase Soy Broth cultures of *Bacillus subtilis*, *Escherichia coli* and *Micrococcus luteus* and *Mycobacterium phlei* – referred to as Tubes A.
- Sterile Trypticase Soy Broth tubes (4 -one for each microorganism) – referred to as Tubes B.
- Glass Marking pen.

Procedure

1. Turn on the Bunsen burner.
2. Vortex culture suspensions of Bacteria given (Tubes A).
3. Place culture suspensions tube near sterile broth tubes (tubes B). Label sterile tubes with name of microorganism and date.
4. Sterilize the inoculation loop as explained above.
5. While holding inoculation loop between thumb and first two fingers of right hand, pick up tube A with left hand and open the cap/cotton plug with last two fingers of right hand.
6. Flame the lip of test tube A.
7. Place the sterile loop into culture A and take loopful of culture.
8. While still holding the inoculum in your right hand, pick up tube B with left hand and open the cap/cotton plug with last two fingers of right hand.
9. Flame the lip of test tube B gently
10. Place the loop containing droplet of culture in tube B and gently swirl it to transfer the microbes into sterile broth..
11. Take out the loop and continue to hold it in your hand.
12. Flame the lip of test tube B gently and replace the cap/plug which should be still in your right hand. Place tube B back in the test tube rack. Like wise plug the tube A and place in a test tube rack.
13. Sterilize the inoculation loop in flame.
14. Repeat the procedure with all bacterial cultures.

Results

1. Draw and describe the growth seen in each of the four broth cultures.



Bacillus subtilis Growth =	*Escherichia coli* Growth =	*Micrococcus luteus* Growth =	*Mycobacterium phlei* Growth =

Figure 4.1: Growth of bacterial culture

C) Streaking plating bacteria

a) From broth culture to sterile medium plate
b) From one petridish to fresh sterile medium plate

Requirements

- Bunsen burner.
- Inoculation needle.
- Trypticase Soy Broth cultures of bacteria (*Bacillus subtilis and Escherichia coli*) to be transferred (Tubes A).
- Trypticase Soy Agar plate cultures of bacteria (*Bacillus subtilis and Escherichia coli*) to be transferred.
- Sterile petridish having Trypticase Soy Agar medium (4 no. Two for each bacterium).
- Glass Marking pen.

Procedure

Removing inoculum from a broth culture

1. Label the plates and tubes.
2. Turn on the Bunsen burner.
3. Loosen the top of the bottle/ Tube containing the inoculum.
4. Hold the loop in the right hand.
5. Flame the loop and allow to cool.
6. Lift the bottle/test tube containing the inoculum with the left hand.
7. Remove the lid/cotton wool plug of the bottle/test tube with the little finger of the left hand.

8. Flame the neck of the bottle/test tube.
9. Insert the loop into the culture broth and withdraw. At all times, hold the loop as still as possible.
10. Flame neck of the bottle/test tube.
11. Replace the lid/cotton wool plug on the bottle/test tube using the little finger. Place bottle/test tube on bench.

Removing inoculum from a plate culture

1. Sterilize the inoculating loop in the flame of a gas burner.
2. Lift the lid of the culture plate slightly and stab the loop into the agar away from any growth to cool the loop.
3. Scrape off a small amount of the organisms and close the lid

Transferring the inoculum into a petri plate

1. Partially lift the lid of the Petri dish containing the solid medium.
2. Hold the charged loop parallel with the surface of the agar; smear the inoculum backwards and forwards across a small area of the medium
3. Remove the loop and close the Petri dish.
4. Flame the loop and allow it to cool. Turn the dish through 90º anticlockwise.
5. With the cooled loop streak the plate from area A across the surface of the agar in three parallel lines. Make sure that a small amount of culture is carried over.
6. Remove the loop and close the Petri dish.
7. Flame the loop and allow to cool. Turn the dish through 90º anticlockwise again and streak from B across the surface of the agar in three parallel lines.
8. Remove the loop and close the Petri dish.
9. Flame the loop and allow to cool. Turn the dish through 90º anticlockwise and streak loop across the surface of the agar from C into the centre of the plate
10. Remove the loop and close the Petri dish. Flame the loop.
11. Seal and incubate the plates inoculated with *Bacillus subtilis and Escherichia coli* **at 37°C upside down** (lid on the bottom) to prevent condensing water from falling down on the growing colonies and causing them to run together in inverted position.

Results

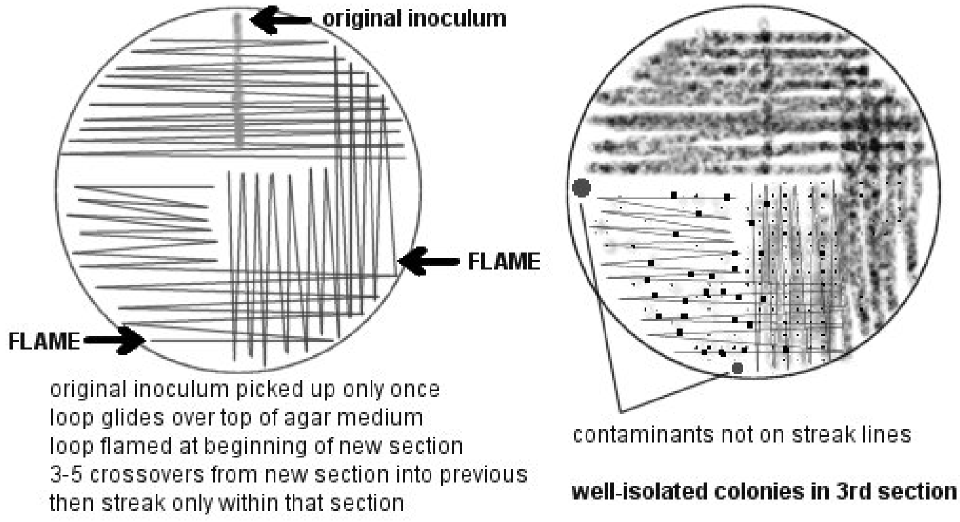


Figure 4.2: Streak plate technique

Expressing results

Bacterial colonies contain millions of cells and exhibit diverse morphologies; however, all isolated colonies produced on streak plates arise from a single bacterial cell. When evaluating colony morphology, use specific terms to describe the shape, elevation, colony margin shape, and surface texture (Figure 4.3). Colony size and colour are also useful features that are noted. All of these characteristics may be useful in the initial identification of unknown bacteria. Colonies that have different morphologies may be considered to contain different bacterial species. However, colonies that appear to be similar in morphology are not always the same bacterial species.

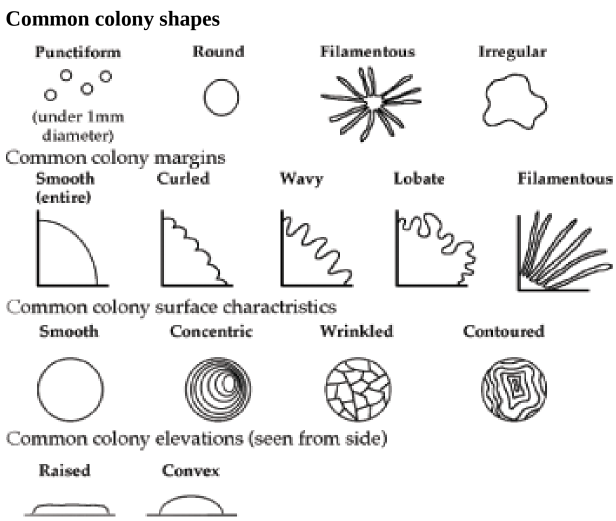


Figure 4.3: Terminology used to describe colony morphology

4.2.2 Observations

Obtain your streak plate from the incubator and visually examine the different regions:

1. Notice a dilution effect as you move from region to region.
2. Look for isolated individual colonies present.
3. Note different types of colony morphologies present.
4. Measure the size (diameter or length) and record the colony colour in Table 1.

Table 1: Colony characteristics of two bacterial colonies isolated using streak plating

Colony Size (mm)	Colour	Shape	Margin	Surface	Elevation
1.					
2.					

4.3 PRECAUTIONS

- Operations must not be started until all requirements are within immediate reach and must be completed as quickly as possible.
- Carry out all microbiological operations in a laminar flow hood.
- Wear gloves and lab coat to protect yourself but also to prevent dry skin and microorganisms from contaminating your samples.
- Use plugs made of non-absorbent cotton wool in test tubes and pipettes to prevent microorganisms from passing in or out and contaminating either the culture or the environment. The cotton wool must remain dry because this filtration property is lost if the cotton wool becomes moist – hence the use of non-absorbent cotton wool.
- For use in test tubes a plug should be properly made to ensure that it can be held comfortably without being dropped and its shape and form are retained while being removed from and returned to a test tube several times.
- Disinfect all surfaces prior to use with a disinfectant solution.
- Swab down the working surface liberally with 70% ethanol.
- Periodically spread a solution of 70% ethanol over the exterior of gloves to minimize contamination. Replace them if torn.
- In case of any spill, spread a solution of 70% alcohol and swab immediately with non-linting wipes.
- Discard gloves after use and do not wear them when entering any other lab area.
- Bring into the work area only those items needed for a particular procedure.
- Leave a wide clear space in the centre of the hood (not just the front edge) to work on. Do not clutter the area to prevent blockage of proper air flow and to minimize turbulence.
- Swab with 70% alcohol all glassware (medium bottles, beakers, etc.) before placing them inside the hood.
- Arrange the work area to have easy access to all of it without having to reach over one item to get at another (especially over an open bottle or flask).
- Use sterile wrapped pipettes and discard them after use into a biohazard waste container.

- Check that the wrapping of the sterile pipette is not broken or damaged.
- Vessels must be open for the minimum amount of time possible and while they are open all work must be done close to the Bunsen burner flame where air currents are drawn upwards.
- Discard any contaminated material immediately.
- Never perform mouth pipetting. Pipetting aids must be used.
- When handling sterile containers with caps or lids, place the cap on its side if it must be laid on the work surface.
- Make sure not to touch the tip of the pipette to the rim of any flask or sterile bottle.
- Clean the work area when finished by wiping with 70% alcohol.

EXPERIMENT 5 VISUAL AND MICROSCOPIC EXAMINATION OF RAW AND PROCESSED PRODUCT

Structure

5.1 INTRODUCTION

Isolation and identification of microbial food contaminants help to understand how infectious agents enter and spread through the food chain. There is a need to estimate the risk that food borne pathogens pose to human health in a national and international context and to identify possible interventions to reduce or eliminate these risks.

Objectives

After studying and performing this experiment, you should be able to:

- take visual observations of food samples
- visualize food-borne micro-organisms under the microscope.

5.2 EXPERIMENT

5.2.1 Principle

The potential for food to become contaminated with chemical substances or microorganisms starts from the time it is harvested and continues right through until the time it is eaten. The examination of food samples is one of the most important tasks:

Initial record of specimen as received

- Examine the specimen carefully for information such as to how it was received, condition (frozen, fresh), time, date, mode of delivery and write description of the specimen immediately.
- Examine seals for faults or damage and describe and note the details on the label.
- Weigh/ Measure the specimen as received and prior to opening.

Odour and taste

- Smell the food. The odour of a food can give clues to the nature of the complaint (volatile substances, deterioration, chemical taints etc.) Food may be required to be tasted CAREFULLY at this point.

Spoilage

- Visually observe spoilage by turbidity, gas production, bubbling etc.

Mouldy food

- Document a full description of the affected areas recording the types of colonies present, their colours and their textures. Measure the area(s) of suspect mould as soon as possible and in three dimensions if applicable. Ensure that the dimensions and numbers of individual colonies are noted.

Microscopic Examination of Foods

Principle

Microscopes are instruments that are capable of producing a magnified image of a small objects including microorganisms. In a food microbiology laboratory Compound Microscopes are most commonly used. These microscopes are light illuminated. They are used in observation and description of the microscopic morphology of bacteria, fungi, parasites and host cells in various stained and unstained preparations.

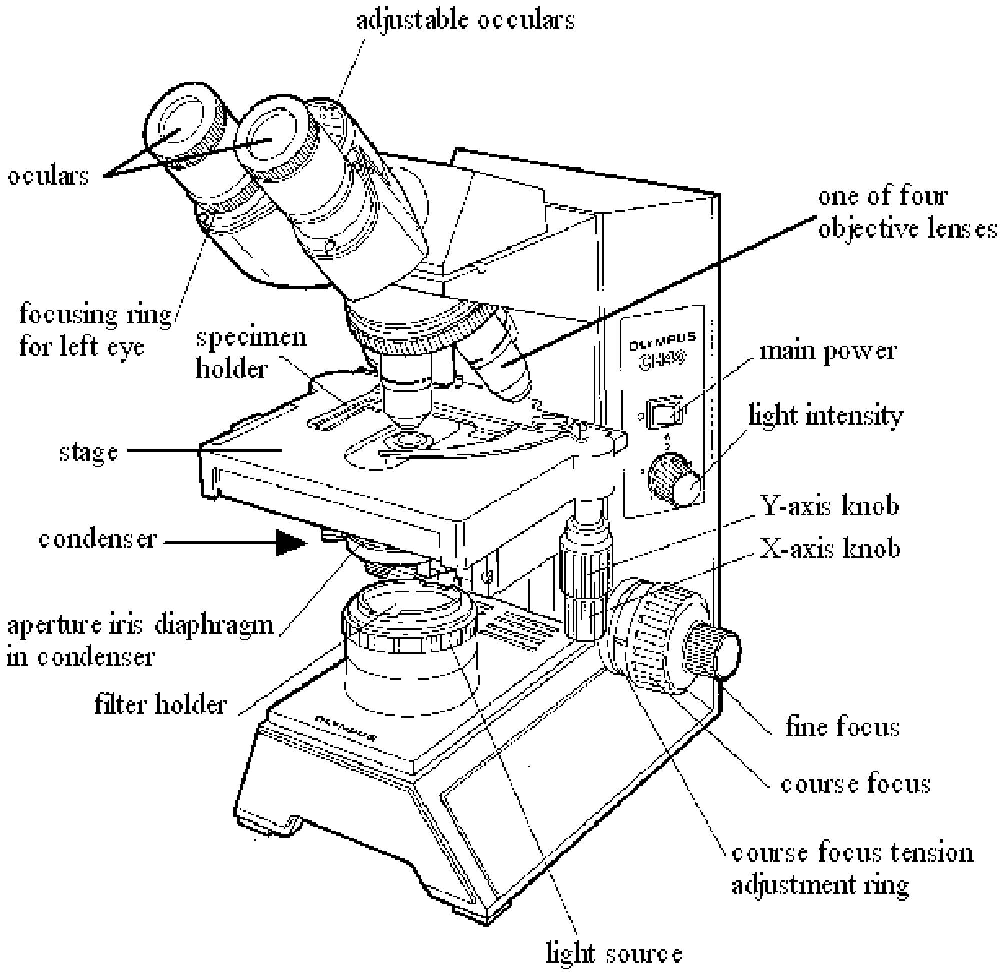


Figure 5.1: Labelled diagram of a compound microscope

Procedure to Focus the Specimen in Microscope

1. Obtain a prepared slide of contaminated food/ isolated microorganism. Mount the slide onto the stage of the microscope.

2. Start with the lowest power objective in place. Using the course adjustment knob, move the objective lens to its lowest point. Look through the ocular and focus upward with the coarse adjustment until an image comes into view. Use the fine adjustment to obtain maximum clarity. From this point on, do not use the coarse adjustment; doing so can result in damage to the lens, slide or both. Adjust the iris to allow enough light for maximum visibility and contrast. Usually, this will be about half the maximum iris opening. Too much light can wash out the details of the image.

3. Move the slide to a point of interest. Move the next objective lens into place and adjust the fine focusing knob, and adjust the iris as necessary. Repeat this step with the highest power, non-oil lens.

4. Note that as the power of the objective lens increases, the distance between the objective and the specimen (working distance) decreases. Also, as magnification increases, the field of view (visible area) and depth of field/focus (visible thickness) decrease. Moving the fine adjustment up and down allows viewing of other areas along the depth of thickness of the specimen).

5. To use the oil-immersion lens, move the turret halfway between the high-power air (non-oil) lens and the oil lens. Place a drop of immersion oil directly on the slide. Move the oil-immersion lens into place and adjust the fine focusing knob. Adjust the iris as necessary. Make sure that the immersion oil does not get on the air lenses. Make note of the differences and similarities between the organisms.

6. After using the oil lens for a specimen, wipe the lens with a piece of lens paper. Do not use anything but lens paper to clean microscope lenses. Usually, lens-cleaning fluids are not necessary unless the lens is exceptionally dirty.

For Getting the Best Possible Image

1. Use lens tissue, to clean the ocular and objective lenses; do not use any other kind of paper. You may also need to clean the slide.

2. Always begin to focus the microscope with the low power, coarse focusing knob.

3. For best viewing at high power, white light is essential. The higher the power of the objective lens, the less will be the depth of field.

Microorganism's Morphology Using the Microscope

Moulds

Mould mycelium and spores can be observed in unstained wet mounts at magnifications of x100 although direct observations of "mouldy" material through the lid of a Petri dish or specimen jar at lower magnifications with the plate microscope are also informative (but keep the lid on!). Routine identification of moulds is based entirely on the appearance of colonies to the naked eye and of the mycelium and spores in microscopical preparations.

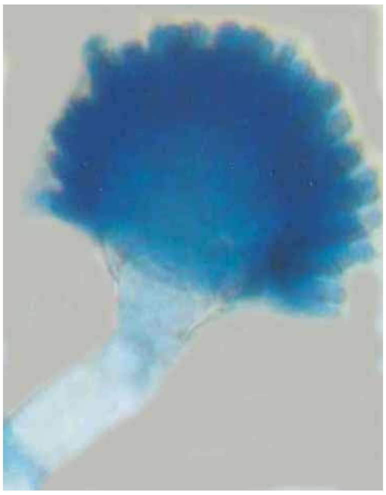


Figure 5.2: ***Aspergillus sp.*** **under microscope**

Yeast

Yeast can be seen in unstained wet mounts at magnifications ×100.

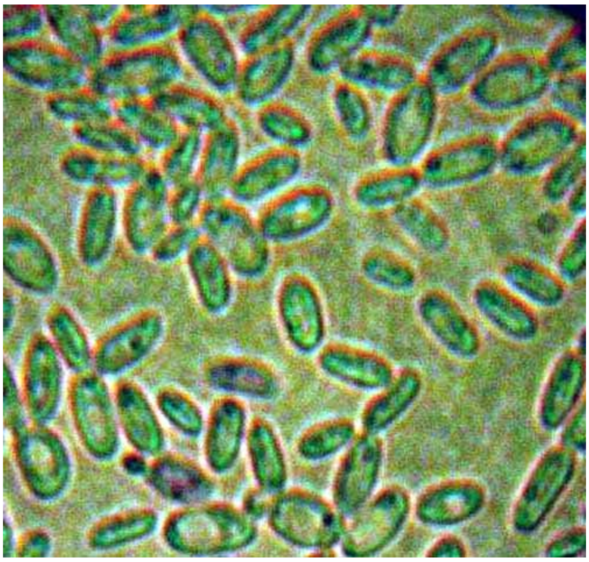


Figure 5.3: Yeast under microscope

Bacteria

Bacteria are much smaller and can be seen unstained at ×400 but only if the microscope is properly set up and all that is of interest is whether or not they are motile. A magnification of ×1000 and the use of an oil immersion objective lens for observing stained preparations are necessary for seeing their characteristic shapes and arrangements. If there is doubt that a food has caused food poisoning or has undergone microbial spoilage, the original product or a low serial dilution of it should be used to prepare a slide for direct microscopic examination. The Gram stain reaction and cellular morphology of the bacteria on the slide may indicate the need for other types of examination. A microscopic examination must be made, even though the food may have undergone heat treatment and the microorganisms involved may no longer be viable.

5.2.2 Requirements

1. Glass slides, 25 x 75 mm, with etched portion for labelling; 1 slide for each blended food sample (10^{-1} dilution)
2. Wire loop, 3-4 mm, platinum-iridium or nichrome, gauge No. 24 or 26
3. Gram stain reagents

Hucker's crystal violet

Solution A

Crystal violet (90% dye content) 2 g

Ethanol, 95% 20 ml

Solution B

Ammonium oxalate 0.8 g

Distilled water 80 ml

Mix solutions A and B. Store 24 h and filter through coarse filter paper.

Gram's iodine

Iodine 1 g

Potassium iodide (KI) 2 g

Distilled water 300 ml

Hucker's counterstain (stock solution)

Safranine O (certified) 2.5

Ethanol, 95% 100 ml

Working solution: Add 10 ml stock solution to 90 ml distilled water.

1. Compound Microscope, with oil immersion objective lens (95-100X) and 10X ocular
2. Immersion oil
3. Methanol
4. Xylene

5.2.3 Procedure

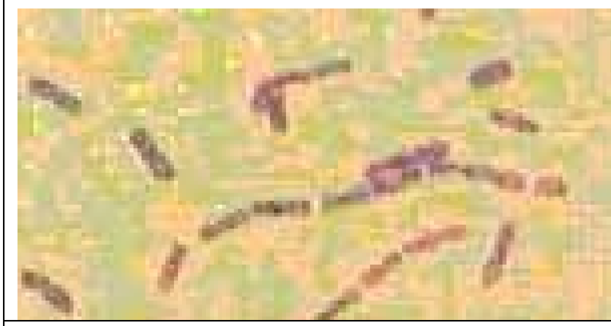
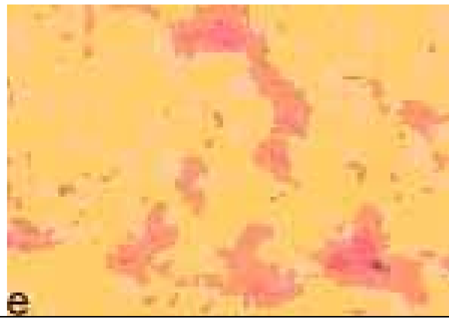
1. Prepare film of blended food sample (10^{-1} dilution).
2. Air-dry films and fix with moderate heat by passing films rapidly over Bunsen or Fisher burner flame 3 or 4 times. Alternatively, air-dry films and fix with methanol 1-2 min, drain excess methanol and flame or air-dry (this is particularly helpful for foods with a high sugar content).
3. Cool to room temperature before staining.
4. De-fat films of food with high fat content by immersing films in xylene 1-2 min; then drain, wash in methanol, drain, and dry.
5. Stain film by Gram-staining procedure.

Procedure for gram staining

1. Fix air-dried films of food sample in moderate heat. Stain films 1 min with crystal violet-ammonium oxalate solution.
2. Wash briefly in tap water and drain. Apply Gram's iodine for 1 min. Wash in tap water and drain.
3. Decolorize with 95% ethanol until blue color is no longer released (about 30 s). Alternatively, flood slides with ethanol, pour off immediately, and reflood with ethanol for 10 s.
4. Wash briefly with water, drain, and apply Hucker's counterstain (safranine solution) for 10-30 sec. Wash briefly with water, drain, blot or air-dry, and examine.
5. Examine under oil immersion and 10X ocular; adjust lighting systems to Koehlor illumination.
6. Examine at least 10 fields of each film, noting predominant types of organisms, especially clostridial forms, Gram-positive cocci, and Gram-negative bacilli.

5.2.4 Observations

- Observe the bacteria under the microscope.

	
Gram positive bacterium	Gram negative bacterium

- Record the Results in table given below.

Table 1: Gram characteristic, size, shape of two bacterial as determined following Gram staining and observation using a compound microscope

Bacterium	Gram Reaction	Cell Size (µm)	Cell Shape
Unknown 1			
Unknown 2			

5.2.5 Results

- Large numbers of Gram-positive cocci on the slide may indicate the presence of staphylococcal enterotoxin, which is not destroyed by the heat treatments that destroy enterotoxigenic *Staphylococcus aureus* strains.

- Large numbers of sporeforming, Gram-positive rods in a frozen food specimen may indicate the presence of *Clostridium perfringens*, an organism that is sensitive to low temperatures. Other Gram-positive, sporeforming rods such as *Clostridium botulinum* or *Bacillus cereus* may also be present in the food.
- When the microscopic examination of suspect food discloses the presence of many Gram-negative rods, consider the symptoms and incubation periods reported for the illness under investigation and select the specific examination method for isolating one or more of the following genera: *Salmonella*, *Shigella*, *Escherichia*, *Yersinia*, *Vibrio*, or *Campylobacter*.

EXPERIMENT 6 ENUMERATION OF BACTERIA BY DILUTION AND PLATING

Structure

6.1 INTRODUCTION

The ability of microorganisms to grow and reproduce in food products is well known. Microorganisms may cause spoilage of the food product. Because of their very small size, counting the number of bacteria in a food sample can be difficult. Although direct counts are possible with a microscope, they require a lot of time and expertise. An easier method is to spread bacteria over a wide area (i.e. nutrient agar plate) and count the number of colonies that grow. If the bacteria are spread out enough, each bacterial cell in the original sample should produce a single colony. Usually, bacterial samples must be diluted considerably to obtain reasonable counts.

Objectives

After studying and performing this experiment, you should be able to:

- enumerate bacteria in food samples; and
- isolate pure colonies of bacteria.

6.2 EXPERIMENT

6.2.1 Principle

Since bacterial cell numbers are usually very high in your original sample, plating out this sample in an undiluted fashion would just lead to the creation of a bacterial lawn (a smear of many, many individual bacteria colonies that are all growing next to or on top of one another). Bacterial cell numbers need to be reduced, which is done by repeatedly diluting the amount of bacteria you have in your sample. A small amount of bacteria sample is mixed with a diluent solution (such sterile water or nutrient broth), and then successive dilutions are made. A small amount of each of the diluted bacteria samples is then spread onto an agar plate. The numbers of bacteria colonies that grow on each plate are counted. By working backwards using multiplication with the "dilution factor" (the number of times that you have diluted the bacteria sample with the diluent solution), you will be able to make a determination of the numbers of bacteria in your original sample.

For example, 10,000,000 cell per ml diluted to 100 cells per ml. It is virtually impossible to count 10,000,000 cells on the surface of the agar. However, it is much easier if we dilute the sample and only have to count 300 cells. Diluting is performed in increments because we must obtain a plate with between 30 and 300 colonies (for statistical purposes). Figure 6.1 shows how isolated colonies should look like.

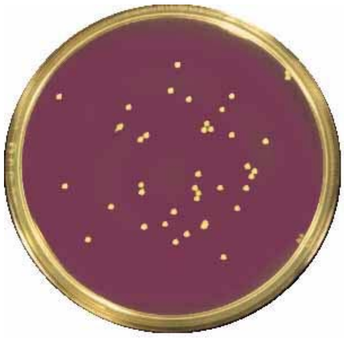


Figure 6.1: Bacterial colonies separated by spread plate method

6.2.2 Requirements

- Nutrient agar plates (6)
- Large sterile tubes (2)
- Tubes with 9 ml of sterile nutrient broth (11)
- Sterile transfer pipettes
- Sterile sticks (2)
- Micropipettor
- Bacteria spreader
- 70% alcohol
- Food samples (say Sample A has been stored in a refrigerator for 4 days;
- Sample B has been stored frozen)

6.2.3 Procedure

DAY 1

1. Label 9 dilution broth tubes as follows:

   A 10^{-2}, A 10^{-3}, A 10^{-4}, A 10^{-5}, A 10^{-6}, A 10^{-7},
   B 10^{-2}, B 10^{-3}, B 10^{-4}

2. Label 6 agar plates as follows:

   A 10^{-6}, A 10^{-7}, A 10^{-8}
   B 10^{-3}, B 10^{-4}, B 10^{-5}

3. Label one large sterile tube A and the other large sterile tube B. Weigh aseptically 1 gram of sample A, and place it in sterile tube A. Add the contents of one tube of dilution broth to the food sample, and shake the sample until the suspension appears fairly uniform. Repeat this with sample B and sterile tube B.

4. Serial Dilutions

   Precaution: You must use a new sterile pipette for each of the dilution steps.

Use a sterile pipette to transfer 1 ml of the suspension from large tube A to the culture tube labeled A 10^{-2}. Mix the contents thoroughly by pipeting up and down several times. Use a new pipette to transfer 1 ml from tube A 10^{-2} to tube A 10^{-3} and mix thoroughly as before. Continue this series of dilutions into tubes A 10^{-4}, A 10^{-5}, A 10^{-6} and A 10^{-7}.

Repeat this series of dilution using sample B. Transfer 1 ml of suspension from large tube B into tube B 10^{-2} and mix thoroughly. Serially transfer, as before, into tubes B 10^{-3} and B 10^{-4}.

5. Plating bacteria

   Use a micropipettor to withdraw 0.1 ml of liquid from tube A 10^{-5} and place it onto the surface of the agar plate labeled A 10^{-6}. (NOTE: Plating 0.1 ml of a 10^{-5} dilution will give you the same number of colonies as plating 1 ml of a 10^{-6} dilution; the agar plate cannot absorb 1 ml of liquid, so the smaller volume is used.)

   Sterilize the bacterial spreader by dipping it into a beaker of alcohol. Remove and shake off the excess. Carefully run the spreader through the flame of a Bunsen burner and allow the alcohol to burn off. Cool the spreader by holding it against the condensation on the inside of the petri dish lid. Gently spread the liquid culture onto the surface of the agar by moving the spreader in a circular manner while rotating the plate. This will ensure an even distribution of bacteria.

6. Repeat step 5 with the remainder of the A cultures:

   Spread 0.1 ml from culture tube A 10^{-6} onto plate A 10^{-7}
   Spread 0.1 ml from culture tube A 10^{-7} onto plate A 10^{-8}

7. Repeat step 5 with the B cultures:

   Spread 0.1 ml from culture tube B 10^{-2} onto plate B 10^{-3}
   Spread 0.1 ml from culture tube B 10^{-3} onto plate B 10^{-4}
   Spread 0.1 ml from culture tube B 10^{-4} onto plate B 10^{-5}

8. Allow plates to absorb the cultures, then turn plates upside-down and incubate overnight at 37° C.

Precautions

1. Before plating, be sure to label each plate with its dilution, date and "food".
2. Mix the samples thoroughly before plating.
3. After pipetting the correct amount of sample in each plate, spread the sample with a bactispreader evenly over the entire surface of the agar.
4. Remember to use aseptic technique. Invert plates. Incubate at 37°C.

6.2.4 Observations

On DAY 2, after incubating the plates, count the colonies on the plate. Each colony represents one cell initially plated. For statistical purposes, pick a plate with between 30 and 300 colonies.

PLATE # COLONIES	PLATE # COLONIES
A 10^{-6}	B 10^{-3}
A 10^{-7}	B 10^{-4}
A 10^{-8}	B 10^{-5}
Bacterial count in sample A (refrigerated food):	Bacterial count in sample B (food):

6.2.5 Calculations

Determine the number of cells/gram in the original sample of food by multiplying the number of colonies on a plate by the dilution factor of that plate.

Calculations dilutions made	**X**	**amount inoculated**	=	**"plated dilution"**
dilution factor (simply the inverse of the plated dilution)	X	# colonies	=	# CFUs/ml (or gram) of the original undiluted sample

Example

If a plate labelled 10^{-7} has 87 colonies, then the sample has $87 \times 10^{7} = 8.7 \times 10^{8}$ colonies per gram.

6.2.6 Result

Find the average number of cells/g by adding the results from all of your plates and dividing by the number of plates.

ANNEXURE-1

Composition of different media used for microbial study

1. *Standard Plate Count Agar (SPCA)*

Tryptone	-	5.0g
Yeast extract	-	2.5g
D-glucose	-	5.0g
Agar	-	15.0g
Distilled water	-	1000ml
pH	-	7.0

2. *Nutrient Agar for Bacterial count*

Beef extract	-	3.0g
Peptone	-	5.0g
Agar	-	15.0g
Distilled water	-	1000 ml
pH	-	7.0

3. *Potato Dextrose Agar for Fungal count*

Potato, peeled and diced	-	200g
D-glucose	-	20g
Agar	-	15.0g

Boil 200g of peeled and diced potato for 1 hr in a litre of water. Filter and make up the volume to 1litre and add rest of the constituents.

4. *Violet Red Bile Agar (VRBA) for coliform count*

Yeast Extract	-	3.0g
Peptone	-	7.0g
Sodium Chloride	-	5.0g
Bile Salts	-	1.5g
Lactose	-	10.0g
Neutral red	-	0.03g
Crystal violet	-	0.002g
Agar	-	13.0g
Distilled water	-	1000ml
pH	-	7.4

UNIT 1 PRINCIPLES OF HEAT AND MASS TRANSFER

Structure

1.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- define the basic principles and methods of heat transfer;
- explain the role of heat transfer in heat preservation processes;
- identify the type of food for heat processing;
- determine the heat penetration and calculate the process time in a food; and
- identify the factors affecting heat transfer and apply corrective measures to enhance the process of heat transfer.

1.1 INTRODUCTION

Heat transfer is an important operation in the food industry. Whether it is called cooking, baking, drying, sterilizing or freezing, heat transfer is part of processing of almost every food. Heat transfer is a dynamic process in which heat is transferred spontaneously from one body to another cooler body. The rate of heat transfer depends upon the differences in temperature between the bodies, the greater the difference in temperature, the greater will be the rate of heat transfer.

Temperature difference between the source of heat and the receiver of heat is, therefore, the driving force in heat transfer. An increase in the temperature difference increases the driving force and, thus the rate of heat transfer. The heat passing from one body to another travels through some medium, which in general offers resistance to the heat flow. Both these factors, the temperature difference and the resistance to heat flow, affect the rate of heat transfer.

1.2 HEAT TRANSFER SYSTEM

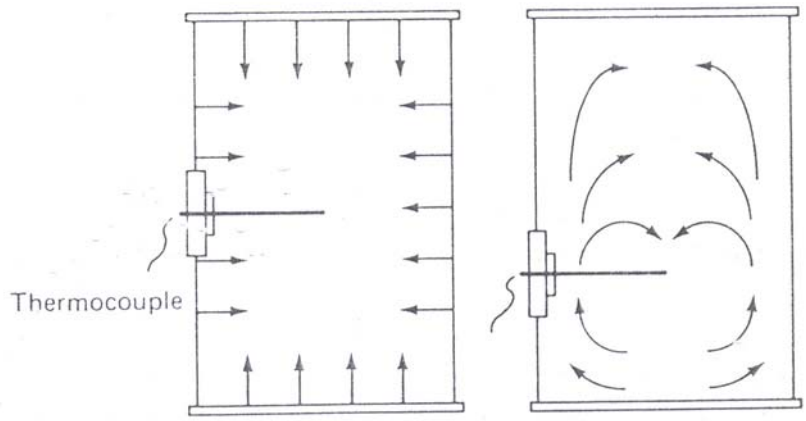
Heat can be transferred from one object to another in three ways: by **conduction,** by **convection** and by **radiation**.

Conduction is the movement of heat by direct transfer of molecular energy within solids. The molecules with greater energy communicating some of this energy to neighbouring molecules with less energy. An example of conduction is the heat transfer through the solid walls of a refrigerated store.

Convection is the transfer of heat by the movement of groups of molecules in a fluid. The groups of molecules may be moved by either density changes or by forced motion of the fluid. An example of convection heating is cooking in a jacketed pan: without a stirrer, density changes cause heat transfer by natural convection; while with a stirrer, the convection is forced.

Radiation is the transfer of heat energy by electromagnetic waves, which transfer heat from one body to another, in the same way as electromagnetic light waves transfer light energy. An example of radiant heat transfer is when a foodstuff is passed below a bank of electric resistance heaters that are red-hot (electric grill).

In general, heat is transferred in solids by conduction and in fluids by conduction and convection (Figure 1.1). Heat transfer by radiation occurs through open space, can often be neglected, and is most significant when temperature differences are substantial. In practice, the three types of heat transfer may occur simultaneously. For calculations it is often best to consider the mechanisms separately, and then to combine them where necessary.



(a) **(b)**

Figure 1.1: Heat transfer in containers by (a) conduction and (b) convection

1.2.1 Conduction

In the case of heat conduction, the equation, heat transfer rate = driving force/resistance, can be applied directly. The driving force is the temperature difference per unit length of heat-transfer path, i.e., temperature gradient. Instead of resistance to heat flow, its reciprocal, **conductance**, is used. This changes the form of the general equation to:

Rate of heat transfer = driving force x conductance, which is:

$$dQ/dt = kA\, dT/dx \qquad (1.1)$$

Where, dQ/dt (JS^{-1})is the rate of heat transfer, the quantity of heat energy transferred per unit of time, A (m^2)is the area of cross-section of the heat flow path, dT/dx (^{0}Cm^{-1})is the temperature gradient, that is the rate of change of temperature per unit length of path, and k (Jm^{-1} s^{-1} ^{0}K or Wm^{-1} ^{0}K^{-1})is the thermal conductivity of the medium. Notice the distinction between thermal conductance, which relates to the actual thickness of a given material (k/x) and **thermal conductivity**, which relates only to unit thickness. Eq. (1.1) is known as the **Fourier equation** for heat conduction.

Thermal conductivity does change slightly with temperature, but in many applications it can be regarded as a constant for a given material. Most foodstuffs contain a high proportion of water and as the thermal conductivity of water is about 0.7 J m^{-1} s^{-1}°C^{-1} above 0°C, thermal conductivities of foods are in the range 0.6-0.7 J m^{-1} s^{-1}°C^{-1}. Ice has a substantially higher thermal conductivity than water, about 2.3 J m^{-1} s^{-1}°C^{-1}. The thermal conductivity of frozen foods is, therefore, higher than foods at normal temperatures.

1.2.2 Convection

Convection heat transfer is the transfer of energy by the mass movement of groups of molecules. It is restricted to liquids and gases, as mass molecular movement does not occur at an appreciable speed in solids. It cannot be mathematically predicted as easily as can transfer by conduction or radiation and so its study is largely based on experimental results rather than on theory.

Newton found, experimentally, that the rate of cooling of the surface of a solid, immersed in a colder fluid, was proportional to the difference between the temperature of the surface of the solid and the temperature of the cooling fluid. This is known as **Newton's Law of Cooling**, and it can be expressed by the following equation.

$$q = h_s A(T_a - T_s) \qquad (1.2)$$

Where, h_s is called the surface heat-transfer coefficient, T_a is the temperature of the cooling fluid and T_s is the temperature at the surface of the solid. The surface heat-transfer coefficient can be regarded as the conductance of a hypothetical surface film of the cooling medium of thickness x_f such that

$$h_s = k_f / x_f$$

Where, k_f is the thermal conductivity of the cooling medium. It is useful at this point, however, to appreciate the magnitude of h_s under various common conditions and these are shown in Table 1.1.

Table 1.1: Approximate range of surface heat transfer coefficients

	hs (J m^{-2} s^{-1}°C^{-1})
Boiling liquids	2400-24,000
Condensing liquids	1800-18,000
Still air	6
Moving air (3 m s^{-1})	30
Liquids flowing through pipes	1200-6000

1.2.3 Radiation

Radiation heat transfer is the transfer of heat energy by electromagnetic radiation. Radiation operates independently of the medium through which it occurs and depends upon the relative temperatures, geometric arrangements and surface structures of the materials that are emitting or absorbing heat.

Radiation of wavelength 0.8-400 μm (infrared) is referred to as thermal radiation or heat rays since electro magnetic radiation with this wavelength is most readily absorbed and converted to heat energy. The infrared radiation is used primarily for surface heating as it is transmitted rapidly to the surface. It is used for dehydration of fruits and vegetables, freeze drying, baking, etc.

Radiation can be significant with small temperature differences as, for example, in freeze-drying and in cold stores, but it is generally more important where the temperature differences are greater. Under these circumstances, it is often the most significant mode of heat transfer, for example in bakers' ovens and in radiant driers.

The basic formula for radiant-heat transfer is the **Stefan-Boltzmann Law**

$$q = A\,\sigma \boldsymbol{T}^4 \tag{1.3}$$

Where, $\boldsymbol{T}$ is the absolute temperature (measured from the absolute zero of temperature at –273°C, and indicated in Bold type) in degrees Kelvin (K) in the SI system, and σ (sigma) is the Stefan-Boltzmann constant = 5.73×10^{-8} J m^{-2} $s^{-1}K^{-4}$ The absolute temperatures are calculated by the formula K = (°C+273).

This law gives the radiation emitted by a perfect radiator (a **black body** as this is called though it could be a red-hot wire in actuality). A black body gives the maximum amount of emitted radiation possible at its particular temperature. Real surfaces at a temperature T do not emit as much energy as predicted by Eq. (1.3), but it has been found that many emit a constant fraction of it. For these real bodies, including foods and equipment surfaces, that emit a constant fraction of the radiation from a black body, the equation can be rewritten

$$q = \varepsilon A\,\sigma \boldsymbol{T}^4 \tag{1.4}$$

Where, ε (epsilon) is called the **emissivity** of the particular body and is a number between 0 and 1. Bodies obeying this equation are called **grey bodies**. Emissivities vary with the temperature $\boldsymbol{T}$ and with the wavelength of the radiation emitted. For many purposes, it is sufficient to assume that for:

* dull black surfaces (lamp-black or burnt toast, for example), emissivity is approximately 1;
* surfaces such as paper/painted metal/wood and most foods, emissivities are about 0.9;
* rough un-polished metal surfaces, emissivities vary from 0.7 to 0.25;
* polished metal surfaces, emissivities are about or below 0.05.

These values apply at the low and moderate temperatures, which are those encountered in food processing. Just as a black body emits radiation, it also absorbs it and according to the same law, Eq. (1.3). Again grey bodies absorb a fraction of the quantity that a black body would absorb, corresponding this time to their **absorptivity** α (alpha). For grey bodies it can be shown that α = ε. The fraction of the incident radiation that is not absorbed is reflected, and thus, there is a further term used, the **reflectivity**, which is equal to (1 – α).

The radiant energy transferred between two surfaces depends upon their temperatures, the geometric arrangement, and their emissivities. For two parallel surfaces, facing each other and neglecting edge effects, each must intercept the total energy emitted by the other, either absorbing or reflecting it. In this case, the net heat transferred from the hotter to the cooler surface is given by:

$$q = AC\sigma\,(\boldsymbol{T}_1^{\,4} - \boldsymbol{T}_2^{\,4}) \tag{1.5}$$

where $1/C = 1/\varepsilon_1 + 1/\varepsilon_2 - 1$, ε_1 is the emissivity of the surface at temperature T_1 and ε_2 is the emissivity of the surface at temperature T_2.

1.2.4 Overall Heat Transfer Coefficients

It is most convenient to use overall heat transfer coefficients in heat transfer calculations as these combine all of the constituent factors into one, and are based on the overall temperature drop. Radiation coefficients, subject to the limitations discussed in the section on radiation, can be incorporated in the overall coefficient. The radiation coefficients should be combined with the convection coefficient to give a total surface coefficient, as they are in series, and so:

$$h_s = (h_r + h_c) \tag{1.6}$$

The overall coefficient U for a composite system, consisting of surface film, composite wall, surface film, in series, can then be calculated as:

$$1/U = 1/(h_r + h_c)_1 + x_1/k_1 + x_2/k_2 + \ldots + 1/(h_r + h_c)_2 \tag{1.7}$$

In Eq. (1.7) often one or two terms are much more important than other terms because of their numerical values. In such a case, the important terms, signifying the low thermal conductance are said to be the **controlling terms**.

1.2.5 Heat Transfer from Condensing Vapours

The rate of heat transfer obtained when a vapour is condensing to a liquid is very often important. In particular, it occurs in the food industry in steam-heated vessels where the steam condenses and gives up its heat; and in distillation and evaporation where the vapours produced must be condensed. In condensation, the latent heat of vaporization is given up at constant temperature, the boiling temperature of the liquid. Two generalized equations have been obtained:

1) For condensation on **vertical tubes or plane surfaces**

$$h_v = 0.94\,[(k^3\rho^2 g/\mu) \times (\lambda/L\Delta T)]^{0.25} \tag{1.8}$$

Where, λ (lambda) is the latent heat of the condensing liquid in J kg^{-1}, L is the height of the plate or tube and the other symbols have their usual meanings.

2) For condensation on a **horizontal tube**

$$h_h = 0.72\,[(k^3\rho^2 g/\mu) \times (\lambda/D\Delta T)]^{0.25} \tag{1.9}$$

1.2.6 Heat Transfer to Boiling Liquids

When the presence of a heated surface causes a liquid near it to boil, the intense agitation gives rise to high local coefficients of heat transfer. A considerable amount of experimental work has been carried out on this, but generalized correlations are still not very adequate. It has been found that the apparent coefficient varies considerably with the temperature difference between the heating surface and the liquid. For temperature differences greater than about 20°C, values of h decrease, apparently because of blanketing of the heating surface by vapours. Over the range of temperature differences from 1 to 20°C, values of h for boiling water increase from 1200 to about 60,000 J m^{-2} s^{-1} $°C^{-1}$. For boiling water under atmospheric pressure, the following equation is approximately true:

$$h = 50(\Delta T)^{2.5} \tag{1.10}$$

Where, ΔT is the difference between the surface temperature and the temperature of the boiling liquid and it lies between 2 and 20°C. In many applications the high boiling film coefficients are not of much consequence, as resistance in the heat source controls the overall coefficients.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List the different methods of heat transfer.

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2. What is the relationship of conduction heat transfer rate with temperature difference? What is the name of the equation used for determining the conduction heat transfer rate?

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3. What is the name of the equation used for expressing the radiative flux from an object? How is it related to temperature and properties of the material?

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4. While estimating the rate of heat transfer between two objects, the temperature of one of the objects is doubled. If convection and radiation are the two modes of heat transfer between the two objects, which mode would increase more and why?

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1.3 TYPE OF FOOD FOR HEAT PROCESSING

There are essentially two types of food when we talk of thermal processing:

1. Acid foods
2. Low acid foods

These two categories of foods differ significantly in their behaviour when thermally processed. The acidity of the food, using the pH scale as a measure of acidity, where 1 = very high acid and 4 = very low acid; the dividing line for **acid foods** and **low-acid foods** is pH 4.6. **Acid foods** can be canned at a temperature of 100°C, while **low-acid foods** must be pressure canned (to a temperature of 115°C). The reason for this is that the toxin-producing, potentially lethal organism, *Clostridium botulinum*, will not grow and produce toxins at a pH below 4.6. Many spoilage microorganisms will not grow between pH 1 and 4.6 either. The most common spoilage microorganisms associated with **acid foods** are yeasts and moulds that can tolerate acid environments.

1. Acid foods

High acid foods contain more natural acids. Many fruits are high acid foods and the presence of these natural acids helps prevent growth of some spoilage microorganisms. If the food product has a high enough acid level, boiling-water temperatures are high enough to destroy spoilage organisms. This is a prevention method for the deadly *Clostridium botulinum* bacteria.

2. Low acid foods

Low acid foods, such as vegetables and meat products, contain very little natural acid. They must be processed at higher temperatures than boiling-water to destroy any *Clostridium botulinum* bacteria. Water boils at 100°C, at sea level, and at a lower temperature at higher elevations. Turning up the temperature under the pot or letting the water boil for a longer time does not raise the temperature of the water above its boiling point. To make water boil at a higher temperature, it has to be put under pressure, such as in a pressure canner. When a food is processed at 1.0 kg/cm^2 pressure, the water boils when it gets to 115°C, rather than at 100°C. This is high enough to kill the bacteria that causes botulism poisoning.

Adjust for Altitude to Ensure Safety

The above values of temperatures have been determined for mean sea level. As we move up the mountains, the atmospheric pressure goes down and water boils at lower temperatures as altitude increases. Lower boiling temperatures are less effective for killing bacteria. You must increase either the process time or canner pressure to make up for lower boiling temperatures.

Because altitude affects pressure and the boiling point of liquid, adjustments must be made when canning foods at altitudes of 300 m above sea level or higher. When using the boiling water bath method, processing time must be increased. Add 5 minutes to processing time for altitudes between 300 m and 1500 m above sea level. When using the pressure canner method, pressure must be increased. If using a dial-gauge pressure canner, process foods at 0.8 bar pressure for altitudes between 600 m and 1200 m and at 0.9 bar pressure for altitudes between 1200 m and 1800 m. If using the weight-gauge pressure canner, use 1.0 bar of pressure.

When you mix low-acid and acid foods, assume that the mixture remains low-acid. Although tomatoes used to be considered an acid food, some are now known to have pH values slightly above 4.6, which means they are low-acid. To safely can them as acid foods in a boiling-water canner, you must add lemon juice or citric acid.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. How are acid and low-acid foods distinguished?

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2. How is a thermal process for an acid food different than that for a low-acid food?

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3. What is the method used to raise the boiling point of water in food processing?

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4. What changes are required for thermal processing of foods at high altitudes?

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1.4 HEAT PENETRATION

Heat penetration studies are required to be conducted for verifying the sterilizing temperature of a load (food) meant for moist heat sterilization. These studies are conducted to ensure that the coolest unit within a pre-defined loading pattern (including minimum and maximum loads) will consistently be exposed to sufficient heat lethality (minimum "F").

Heat penetration curve can be drawn by plotting the logarithmic difference between either retort temperature and product temperature (heating curve) or product temperature and cooling medium temperature (cooling curve) versus time. The purpose of a heat-penetration study is to determine the heating and cooling behaviour of a product/package combination in a specific retort system for the establishment of safe thermal processes and evaluating process deviations. The study is designed to adequately and accurately examine all critical factors associated with the product, package and process, which affect heating rates. A goal in conducting these studies is to identify the worst-case temperature response expected to occur in commercial production as influenced by the product, package and process.

Several product, process, package and measurement-related factors can contribute to variations in the time-temperature data gathered during a heat-penetration test. Establishment of a process requires expert judgment and sound experimental data for determining which factors are critical and the effect of changing those factors both within and beyond established critical limits.

A typical heat penetration curve is shown in Figure 1.2. A broken heating curve occurs when a food is initially heated by convective heating but then undergoes a rapid transition to conductive heating (for example in foods, which contain high concentration of starch, which undergoes a sol-to-gel transition).

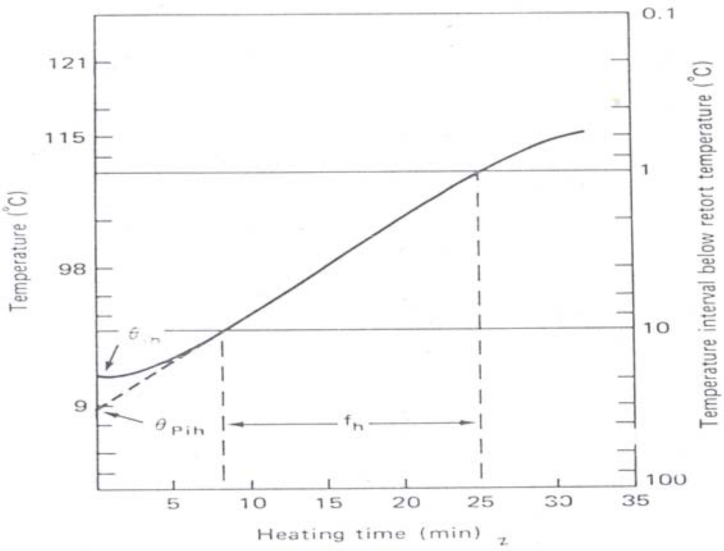

Figure 1.2: Heat penetration curve

There are a number of ways of estimating how effective heat sterilization can be. The thermal death time is the time microbes must be exposed to a particular temperature before they are all dead. Similarly, the thermal death point is the temperature at which all microbes in a sample are killed. Both are very unsatisfactory, since they depend on many factors such as number of microbes present in a sample, analytical conditions and techniques, etc.

1.5 HEAT TRANSFER CHARACTERISTICS OF FOOD

It is necessary to have information on both the heat resistance of microorganisms or enzymes and the rate of heat penetration into the food for determination of process time of a food.

Heat is transferred from steam or pressurized water through the container and into the food. Generally the surface heat transfer coefficient is very high and is not a limiting factor in heat transfer. The following factors influence the rate of heat penetration into a food:

i) Type of product
ii) Size of the container
iii) Agitation of the container
iv) Temperature of the retort
v) Shape of the container. Tall containers promote convection currents in convective heating foods.
vi) Type of container. Heat penetration is faster through metal than through glass or plastics owing to differences in thermal conductivity.

In this section, the objective is to learn as to how the thermal properties of food products affect the heat penetration and the quantity of heat. Two thermal properties of importance are thermal conductivity and thermal diffusivity in determining heat penetration. Specific heat and latent heat are important in determining the quantity of heat required for the process.

I. **Thermal conductivity** is the property indicating the rate at which heat flows through a food product. A product with high thermal conductivity lets the heat flow easily, whereas a material with low thermal conductivity, also known as an insulator, puts resistance to the flow of heat. Fourier's heat conduction equation could be used to derive the units of thermal conductivity, i.e., W/(m°C). It does change slightly with temperature, but in many applications it can be regarded as a constant for a given material. Most foodstuffs contain a high proportion of water and as the thermal conductivity of water is about 0.7 J m^{-1} s^{-1} $°C^{-1}$ above 0°C, thermal conductivities of foods are in the range of 0.6-0.7 J m^{-1} s^{-1} $°C^{-1}$. Ice has a substantially higher thermal conductivity than water, about 2.3 J m^{-1} s^{-1} $°C^{-1}$. The thermal conductivity of frozen foods is, therefore, higher than foods at normal temperatures.

Typical thermal conductivities

Metals: k = 50-400 W/m°C
Water: k = 0.597 W/m°C
Air: k = 0.0251 W/m°C
Insulating materials: k = 0.035 - 0.173 W/m°C

For foods it is represented as

$$k = 0.25\, m_c + 0.155\, m_p + 0.16\, m_f + 0.135\, m_a + 0.58\, m_m$$

Where m is mass fraction and subscripts c: carbohydrate, p: protein, f: fat, a: ash and m: moisture.

or

$$k = 0.55p/100 + 0.26(100-p)/100 \text{ J m}^{-1}\text{ s}^{-1}\text{ °C}^{-1} \text{ above freezing}$$

$$= 2.4p/100 + 0.26(100 - p)/100 \text{ J m}^{-1}\text{ s}^{-1}\text{ °C}^{-1} \text{ below freezing.}$$

Where p is the percentage of water in the foodstuff.

II. Thermal diffusivity is the actual ability of a food to conduct heat to adjacent molecules. Thermal diffusivity is a derived property that is the ratio of thermal conductivity and the product of density and specific heat. The units of thermal diffusivity, therefore, work out to be m^2/s. Higher value of thermal diffusivity means faster heat penetration and vice versa.

III. Specific heat: The specific heat is an important quantity that determines the amount of energy that must be supplied or withdrawn from a unit mass of material in order to increase or decrease its temperature by one degree. Knowledge of the specific heat of a material is, therefore, important in the design of processes such as chilling, freezing, warming, sterilization and cooking. Specific heat has the units of kJ/(kg.K) in SI system of units.

$$\text{Specific heat} = 4.19p/100 + 0.84(100 - p)/100 \text{ kJ kg}^{-1}\text{ °C}^{-1} \text{ above freezing}$$
$$= 2.1\, p/100 + 0.84(100 - p)/100 \text{ kJ kg}^{-1}\text{ °C}^{-1} \text{ below freezing.}$$

p is percentage of water in food stuff

IV. Phase transitions: It is important to determine the temperature at which transitions occur, the enthalpy change associated with a transition, the type of transition involved (exothermic or endothermic), and the quantity of material that undergoes a transition. As an example, we will consider the melting and crystallization of food components. When a material changes its physical state from solid-to-liquid (melting) or from liquid-to-solid (crystallization) it absorbs or gives out heat, respectively. A process that absorbs heat is an endothermic process, whereas a process that evolves heat is an exothermic process. Pure substances usually have very sharp melting or crystallization points and, therefore, all the heat is absorbed or evolved over a narrow range of temperature. Most foods are complex materials and, therefore, do not exhibit sharp transitions from one phase to another. The amount of heat required for the phase change is called the latent heat and has the units of kJ/kg.

$$\text{Latent heat} = 335p/100 \text{ kJ kg}^{-1}$$

This equation and the ones given earlier for thermal conductivity and specific heat represent a considerable over-simplification so they should be used with caution, particularly in the region between –18°C to 0°C. Freezing of foodstuffs occur over a range of temperatures and not at any fixed point.

Some properties of liquids and thermal data for food products are depicted in Tables 1.2 and 1.3, respectively.

Table 1.2: Some properties of liquids

	Thermal conductivity	**Specific heat**	**Density**	**Viscosity**	**Temperature**
	($J\ m^{-1}\ s^{-1}\ °C^{-1}$)	($kJ\ kg^{-1}\ °C^{-1}$)	($kg\ m^{-3}$)	($N\ s\ m^{-2}$)	(°C)
Water	0.57	4.21	1000	1.87×10^{-3}	0
		4.21	987	0.56×10^{-3}	50
	0.68	4.18	958	0.28×10^{-3}	100
Sucrose 20% soln.	0.54	3.8	1070	1.92×10^{-3}	20
				0.59×10^{-3}	80
60% soln.				6.2×10^{-3}	20
				5.4×10^{-3}	80
Sodium chloride 22% soln.	0.54	3.4	1240	2.7×10^{-3}	2
Acetic acid	0.17	2.2	1050	1.2×10^{-3}	20
Ethyl alcohol	0.18	2.3	790	1.2×10^{-3}	20
Glycerine	0.28	2.4	1250	830×10^{-3}	20
Olive oil	0.17	2.0	910	84×10^{-3}	20
Rape-seed oil			900	118×10^{-3}	20
Soya-bean oil			910	40×10^{-3}	30
Tallow			900	18×10^{-3}	65

Milk (whole)	0.56	3.9	1030	2.12×10^{-3}	20
Milk (skim)			1040	1.4×10^{-3}	25
Cream 20% fat			1010	6.2×10^{-3}	3
30% fat			1000	13.8×10^{-3}	3

Table 1.3: Thermal data for some food products

	Freezing point (°C)	Percent water	Specific heat		Latent heat of fusion (kJ kg^{-1})
			Above freezing	Below freezing	
			(kJ kg^{-1}°C^{-1})		
Fruit					
Apples	–2	84	3.60	1.88	280
Bananas	–2	75	3.35	1.76	255
Grapefruit	–2	89	3.81	1.93	293
Peaches	–2	87	3.78	1.93	289
Pineapples	–2	85	3.68	1.88	285
Watermelons	–2	92	4.06	2.01	306
Vegetables					
Asparagus	–1	93	3.93	2.01	310
Beans (green)	–1	89	3.81	1.97	297
Cabbage	–1	92	3.93	1.97	306
Carrots	–1	88	3.60	1.88	293
Corn	–1	76	3.35	1.80	251
Peas	–1	74	3.31	1.76	247
Tomatoes	–1	95	3.98	2.01	310
Water	0	100	4.19	2.05	335

1.6 DEVICES FOR DETERMINATION OF HEAT PENETRATION

There are different types of thermometers available for measuring the temperature in a thermal process and, thereby, permitting the determination of heat penetration.

I. Mercury-in-glass (MIG) thermometer

Each retort system used for the thermal processing is equipped with a MIG thermometer. Aseptic processing systems may have a temperature indicating device other than MIG thermometer as the sole temperature indicator. The MIG thermometer is the reference instrument for all temperature readings, including vent temperature, come-up temperature and process temperature during processing.

It is important that the MIG thermometer be tested/calibrated at the operating temperature of the retort system (i.e., 115□C, 120□C, 125□C etc.) and if possible in the heating medium used in the retort. If the retort is operated at more than one processing temperature or over a wide range of temperatures the MIG thermometer should be checked at all of the temperatures normally used for processing. The MIG thermometers should be tested against a thermometer that can be traced back to a BIS Standard thermometer. The accuracy of the standard thermometer should be checked at least once every 3 years depending upon how it is handled and stored.

II. Temperature recording device

Each retort system is equipped with an accurate temperature-recording device. The recording device provides a continuous record of the temperature in the retort system during thermal processing. Common systems in use are circular or strip charts, which are marked with ink pens, electrical sparks, pressure pins, or which are created by graph plotters at the time temperature readings are received. Electronic temperature monitors and recorders are now available for the purpose and should be utilized for greater accuracy and precision avoiding human errors. A band or ribbon type surface pyrometer is used by processors to monitor container surface temperatures.

III. Temperature sensors

Temperature measurement can be accomplished by essentially five basic methods: (1) liquid-in-glass, (2) resistance thermometry, (3) thermoelectric thermometry, (4) optical/radiation pyrometry, and (5) bi-metal. Investigators are most familiar with the liquid (mercury or alcohol usually) -in-glass and the bi-metal (dial gauge) types. It is possible now that investigators will encounter the use of the optical/radiation pyrometers as well.

i) Resistance thermometry

A resistance thermometer is a temperature-measuring instrument consisting of a sensor (an electrical circuit element whose resistance varies with temperature), a framework on which to support the sensor, a sheath by which the sensor is protected, and wires by which the sensor is connected to a measuring instrument, which is used to indicate the effect of variations in the sensor resistance. Resistance thermometers provide absolute calibration of temperatures in that no reference junctions are involved, and no special extension wires are needed between the sensor and the measuring instrument (as with thermocouples).

The sensors can be of two types: resistance temperature detectors (RTD's) and thermistors. The RTD sensing element is formed of solid conductors (usually in wire form) wound upon an insulating core. The insulating core is usually made of mica or ceramic. The conductors, which are wound in a helical coil to prevent mechanical restraints during thermal expansion, are generally made of platinum; however nickel and copper have been used. Platinum best meets the requirements because being a noble metal, it can be highly refined, it resists contamination, it is mechanically and electrically stable, and the relationship between temperature and resistance is quite linear.

Thermistors (a contraction for "thermally sensitive resistors") are electrical circuit elements formed of solid semi conducting materials such as oxides of nickel, manganese, iron, cobalt, copper, magnesium, titanium, and other metals. The powdered metal is formed under pressure into the desired shape, usually a flat disc. The disc is sintered, leads are attached, and encapsulated in epoxy. The finished thermistor can also be encased in a sheath of plastic, stainless steel, copper or aluminum. Both the RTD and thermistor can be obtained in various configurations.

ii) Thermoelectric thermometry

The thermoelectric thermometer is a temperature measuring instrument consisting of two continuous, dissimilar thermocouple wires extending from a measuring junction to a reference junction with copper connecting wires to a potentiometer. Unlike the resistance types, where power must be supplied to the circuit, the thermocouple circuit generates a measurable low voltage output that is almost directly proportional to the temperature difference between the "hot" junction and the "cold" junction. A unit change in this temperature difference will produce some net change in electromotive force (emf or voltage). Thermoelectric thermometry makes use of the known relationship between a difference in junction temperatures and the resulting emf developed by a thermocouple circuit. The temperature of one junction (reference junction, T1) is held at a constant known value. This is usually accomplished with an ice water (0°C) bath. The temperature of the other junction (measuring junction, T2) is determined by measuring the thermocouple circuit emf and referring to calibration tables for the particular thermocouple materials. The thermocouple junction usually is formed by twisting and fusing the two wires together or they may be butt-welded. The finished element may be used bare or enclosed in a sheath.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write the full forms of the following abbreviations:

   a) MIG thermometer
   b) RTD sensor

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2. How is a thermocouple used for temperature measurement?

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3. What is a thermistor? How does it differ from a RTD sensor?

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4. How is temperature in Kelvin scale related to temperature in Celsius scale?

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1.7 DETERMINATION OF COLD POINT IN A FOOD CONTAINER

In a study, determination of the cold spot was made using data collected for heat penetration curves at 5 potential cold spot locations in the jars in 18 canner loads (Table 1.4). Two levels of two procedural variations were used in testing for process calculations. Temperature profiles were compared for two fill weights (450g, 480g) and two fill temperatures (direct-fill, and after a 10 minute wait, which had means of 84.4°C and 80.4°C, respectively). Process calculation was accomplished by using thermocouples in each of six jars in different canner loads of each of the three fill methods (standard, low initial temperature, and high-fill weight). These jars were processed to 90.5°C plus an additional 5 minutes. Processing was done in a boiling water canner using the stovetop burners of a household gas range. Data were recorded using Type T copper-constantan thermocouples.

Cold Spot Location

- The cold spot for this product and jar combination was located at the geometric centre of the jar, Table 1.4.

- The D value is the number of minutes it takes the straight line portion of the heat penetration plot to pass through one logarithmic cycle.
- A larger D represents a slower rate of heat penetration.

Table 1.4: Cold spot determination of cranberry salsa in pint jars

Thermocouple height in pint jar	Average D value n = 18	Range	Standard deviation
Centre	54.86[1]	48.5-73.4	5.3
½" Below Center	53.89	48.6-64.7	3.9
1" Below Center	51.94	45.8-64.9	4.8
1½" Below Center	48.98	43.0-60.8	4.7
2" Below Center	47.00	41.4-58.0	4.5

[1]Location of cold spot, as determined by largest individual D value (worst-case scenario)

Heat penetration measures the rate at which a product heats during a thermal process. A temperature sensor or thermocouple measures temperature changes in the slowest heating region of the product or container and temperature is monitored on a recording device. The time/temperature data, and heat resistant data for the target microorganism, are used to calculate the scheduled process.

1.8 CALCULATION OF PROCESS TIME

The time/temperature relationship required for desired reduction of microbial population is based on thermal resistance characteristics of the microorganisms. The translation of this information into a form for use by the operator of a commercial system requires integration with the heating and cooling characteristics of the food product within the container. The methods to be presented lead to the establishment of a processing system operator time to ensure that the impact of the thermal process is equivalent to the desired time/temperature for a given microbial population.

One of the first concepts to be understood when establishing process times is **lethality**. The term lethality can be defined as the integrated influence of time and temperature on a microbial population. Lethality is expressed as time at a reference temperature.

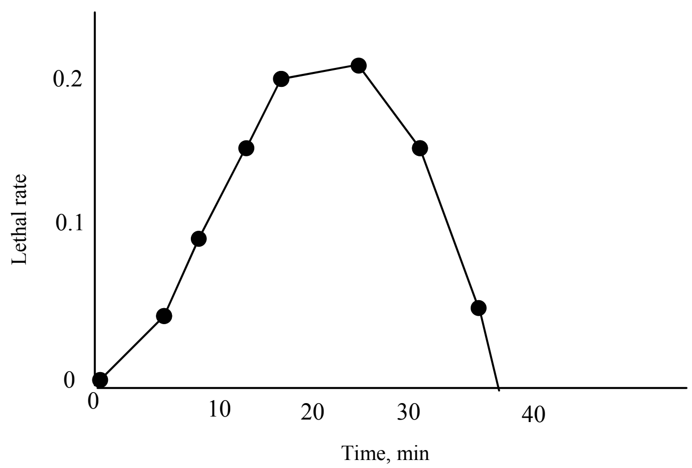

Figure 1.4: Lethal rate curve for typical process in retort

The lethal rate increases gradually with time as the temperature of the product increases. As the product temperature begins to plateau at a magnitude near the heating medium temperature, the lethal rate also plateaus and eventually decreases as the product temperature decreases during cooling. Lethality is expressed in time units for the process accomplished at the heating medium temperature.

The time/temperature relationship representing the process is compared to the process requirement needed to achieve product safety or an established spoilage rate. For example, if the process under consideration is being used to ensure the elimination of *Clostridium botulinum* as a health risk, the lethality for the process must be equal to or greater than the thermal death time for the microbial population.

The D-value or Decimal Reduction Time may be used as a measure. This is defined as the time taken under specified conditions and at a particular temperature to kill 90 per cent of the microbes in a sample. Only 10 per cent or 1/10 of the original number of microbes survive the decimal reduction time: hence its name. D-values can be determined from survivor curves when the log of population is plotted against time.

$$D_{\text{reference temperature}} = \text{Time}/(\text{Log}_a - \text{Log}_b)$$

Where a = the initial population, and b = the survivors after a time interval. F value is a mathematically calculated number that describes the total lethal effect of the process at the slowest heating point in a food container. It is the equivalent, in minutes at a given temperature, of all heat considered with respect to its capacity to destroy spores or vegetative cells of a particular microorganism.

The effectiveness of a canning process is determined from a combination of experimentation and calculation. Processing parameters are expressed in terms of a series of symbols of which D, z, and F are key. When bacterial spores are heated to a lethal temperature as during retorting of canned foods, the death of most species approximates a first order chemical reaction that can be described by a straight line on a semi-logarithmic graph paper. Figure 1.4 shows a hypothetical result from heating a species of spore at 115°C (240°F).
In Figure 1.5, one minute is required to reduce the survivors from 10,000 to 1,000 or a 90 per cent reduction (one log reduction). Similarly, one minute is required to reduce the survivors from 1,000 to 100 per gram of food and so on until only 0.01 of a spore is present in 1 gram of food-which really means that there remains only one living spore for each 100 grams of food. This time to reduce the survivors by 90% is the Decimal reduction (D) value or in Figure 1, D_{115} = 1 min. The subscript after the D indicates temperature at which the D value was determined. Many factors affect the D value, such as the species of spore, and the kind of food the spore is suspended in.

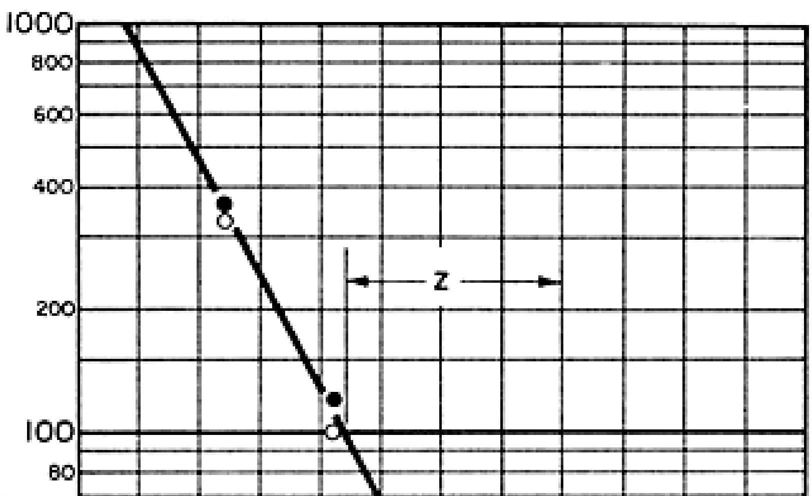

Figure 1.5: Thermal death time curve for *Clostridium botulinum*

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is Decimal Reduction Time (D)? How is it determined?

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2. What is F value and how is it related to D value?

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3. Name the microorganism that is considered in the determination of thermal processing.

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4. What is meant by lethality in food processing? How is it related to various process parameters?

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1.9 FACTORS AFFECTING HEAT PENETRATION

There are many factors, which affect the heat transfer into the food. Generally the surface heat transfer coefficient is very high and is not a limiting factor in heat transfer. The following factors are important which influences the rate of heat penetration into a food:

1. **Type of product:** Liquid or particulate food (for example peas in brine), where natural convection current is established, heat faster than solid food (for example meat pastes and corned beef), where heat is transferred by conduction. The low thermal conductivity of food is a major limitation to heat transfer in conduction heating.

2. **Size of the container:** Heat penetration to the centre is faster in small containers than in large containers.

3. **Agitation of the container:** End-over-end agitation (Figure 1.6) and, to a lesser extent, axial agitation increases the effectiveness of natural convection curie: and thereby increases the rate of heat penetration in viscous or semi-solid foods (for example beans in tomato sauce).

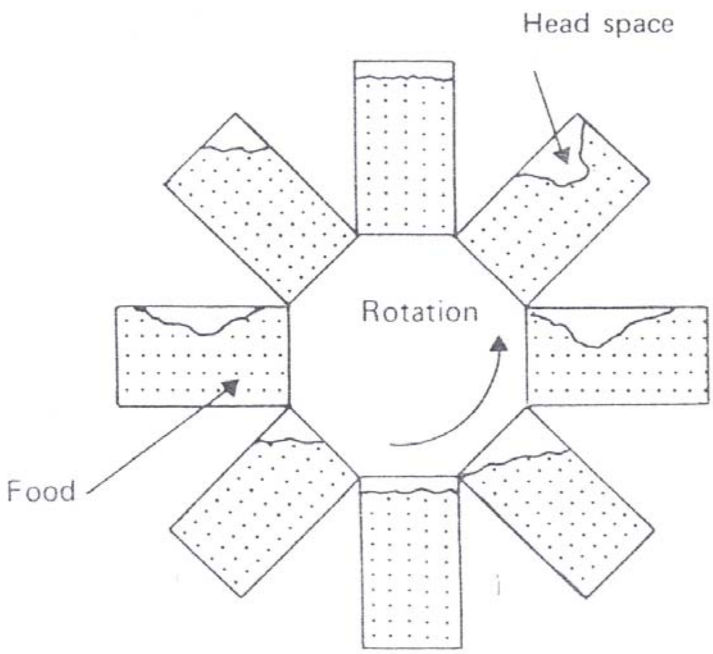

Figure 1.6: End-over-end agitation of containers

4. **Temperature of the retort:** A higher temperature difference between the food and the heating medium causes faster heat penetration.

5. **Shape of the container:** Tall containers promote convection currents in convective heating foods.

6. **Type of container:** Heat penetration is faster through metal than through glass or plastics owing to differences in thermal conductivity.

1.10 LET US SUM UP

We have in this unit learnt the basic concept of heat transfer. Heat is transferred by conduction, convection or radiation modes in a given situation. The methods of temperature measurement include mercury-in-glass (MIG) thermometers, resistance temperature detectors, thermistors, thermocouples and radiation pyrometers. Temperature measurements permit us to evaluate heat penetration rates in the thermal processes so as to determine the process durations to achieve acceptable sterilization levels. These levels differ for acid and less acid foods. If the pH level is below 4.6 the food is classified as an acid food. However, if the pH is equal to or more than 4.6, the foods are low-acid and the process temperatures would have to be more than 100°C. Temperatures more than 100°C are achievable through raising process pressure above that of the ambient. It is important to identify the cold spot in the sterilization process because the heat penetration to that spot will control the overall effectiveness of the process. Decimal reduction time at a given reference temperature is used to fix the process time. Usually, 12 logarithmic cycles are allowed for the microbial population reduction and, thus, the process time F is equal to 12 D. The factors responsible for affecting the temperature distribution and heat penetration rate need to be given due consideration for finalizing the process durations.

1.11 KEY WORDS

Conduction	:	Exchange of molecular energy directly exchanged, from the hotter to the cooler regions.
Convection	:	Transfer of heat by the movement of groups of molecules in a fluid.
Radiation	:	Transfer of heat energy by electromagnetic waves.
Black body	:	It is a body which absorbs all incident light on it.
Grey body	:	Body which partially absorbs and partially reflects incident light falling on it.
Fourier equation	:	It is the general equation guiding conduction heat transfer.
Newton's law of cooling	:	It is the guiding principle behind convective heat transfer.
Radiation pyrometers	:	Measures temperature of a distant / hot object without coming into contact with it.
Decimal reduction time	:	Time required for reducing the microbial population to one tenth of its initial number.
Microbial lethality	:	Time temperature combination to kill all microorganisms including its spores.

1.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answers should include the following points:

1. The different methods of heat transfer are: Conduction, Convection and Radiation.

2. The rate of conduction heat transfer increases as the temperature gradient increases.

   The equation, $dQ/dt = kA\ dT/dx$ is known as **Fourier equation** of heat conduction.

3. The basic formula for radiant-heat transfer is the **Stefan-Boltzmann Law,** $q = \in \sigma \boldsymbol{T}^4$.

   As indicated in the equation, the radiative heat flux q, is proportional to the fourth power of temperature. That means for any increase in temperature the flux increases much faster. The emissivity of the object, $\in$, indicates its capacity in relation to a black body to emit thermal radiation. The value of $\in$ is in the range of 0-1; a black body has $\in = 1$ and a perfectly reflective body has $\in = 0$. The σ is Stefan-Boltzmann constant.

4. If the temperature of one of the objects is doubled, it means the temperature difference between the two objects has increased. Since convection is directly proportional to the temperature difference, it will increase in proportion to the temperature difference. On the other hand the radiation heat transfer is proportional to the difference in the fourth power of the temperatures of the two objects, the radiation heat transfer will increase much more steeply. You can therefore, appreciate that the radiation heat transfer increases much faster than the conduction or convection when the temperature difference between two objects increases.

Check Your Progress Exercise 2

Your answers should include the following points:

1. The acid and low-acid foods are distinguished on the basis of pH. The foods with pH less than 4.6 are called acid and the foods with pH more than 4.6 are called low-acid foods.

2. The thermal process for an acid food consists of treating it in a 100°C boiling water bath, whereas the low-acid food must be pressure treated to a temperature of 115°C or higher to kill the spoilage causing microorganisms.

3. To make water boil at a temperature higher than 100°C in food processing, it has to be put under pressure, such as in a pressure canner. When a food

is processed at 1.0 kg/cm^2 pressure, the water boils when it gets to 115°C, rather than at 100°C.

4. At higher altitudes the atmospheric pressure goes down and water boils at lower temperatures. Thus, to make the thermal processing effective, either the process time or canner pressure must be increased to make up for lower boiling temperatures. That means pressure treatment may be required even for acid foods.

Check Your Progress Exercise 3

Your answers should include the following points:

1. a) Mercury-in-Glass (MIG) Thermometer
   b) Resistance temperature detector sensors

2. A thermocouple is made by joining two dissimilar metals. When one of the junctions is at a different temperature than the surrounding temperature, then a small voltage is developed which can then be measured across the two leads at the other junction. When provision is made in the circuit to take care of the reference point such as the freezing point of water, then the resultant voltage is calibrated in terms of temperature difference between the reference point and the temperature of the junction.

3. A thermistor is normally a thermally sensitive material whose electrical resistance changes with temperature. This change in resistance is calibrated in terms of temperature. It differs from a resistance temperature detection (RTD) sensor in terms of its sensitivity. As a result a thermistor is able to sense very small changes in temperature as compared to a RTD sensor.

4. K = (°C + 273), where K and C are units of temperature in Kelvin scale and Celsius scale.

Check Your Progress Exercise 4

Your answers should include the following points:

1. The Decimal Reduction Time or D-value is defined as the time taken to kill 90% of the microbes in a sample under specified conditions and at a particular temperature. D-values are determined from survivor curves when the log of population is plotted against time.

   $$D_{\text{reference temperature}} = \text{Time}/(\text{Log}_a - \text{Log}_b)$$

   Where a = the initial population, and b = the surviving population after a time interval.

2. The F value for a process is the number of minutes required to kill a known population of microorganisms in a given food under specified conditions. This F value is usually set at 12 D values and the resultant microbial population is extremely low such as one microbe in 10,000 cans (say).

3. *Clostridium botulinum* is the reference microorganism, which is used in determining the different parameters related to thermal processing.
4. Lethality is defined as the integrated influence of time and temperature on a microbial population. It is expressed in time units for the process accomplished at the heating medium temperature. For e.g., a thermal process may require 65 min at 115°C of steam temperature for a given food product to achieve full lethality.

1.13 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port, Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.

3. Nielsen, S.S. (1998) Introduction to Food Analysis. Aspen Publications Inc., Maryland.

UNIT 2 HEAT APPLICATION

Structure

2.0 OBJECTIVES

After reading this unit, you should be able to:

- enumerate processes commonly used in processing of fruits and vegetables based on heat application;
- state difference between direct and indirect method of heat transfer;
- identify various types of heat exchangers;
- describe important features of process equipment used for blanching, pasteurization, sterilization and aseptic processing; and
- explain the principle of microwave and ohmic heat transfer.

2.1 INTRODUCTION

We have studied the basic principles of heat transfer in the previous unit. Now, in this unit, we will go through the heat application aspects in relation to processing of fruits and vegetables. The subject shall be of great interest to us as processes based on application of heat form the core of food preservation and processing operations. In fact, thermally processed foods constitute a large part of the industry. As a post-harvest technician or entrepreneur or food technologists, it is essential for us to know about type of heating processes and equipment available so that the twin objectives of preservation and value addition could be achieved effectively and efficiently. Further, understanding of some of the basic thermal processing principles will help in selecting the processing parameters which would ensure maximum retention of sensory and nutritional attributes.

The important conventional as well as new processes such as blanching, pasteurization, sterilization and aseptic processing, microwave, etc., along with associated equipments have been discussed in this unit. In most of these operations, the heat transfer takes place in the form of convection and conduction. Two different principles are used in heat application. In one case, the heating medium is mixed with product to be heated. This is called direct heating and is used: (a) to heat water – steam is injected directly into the water, and (b) application of direct heating in aseptic processing either through injection or infusion. The direct method of heat transfer is efficient for rapid heating. It does, however, involve mixing of the product with the heating medium, and this necessitates strict demand on the quality of the heating medium. Indirect heat transfer is the most commonly used in food processing operations. In this method, a partition is placed between the product and the heating or cooling medium. Heat is then transferred from the medium, through the partition into the product. Most of the heat exchangers in the industry are designed on this principle. General principles governing heat transfer and response of fruits and vegetables to heat energy can be applied to all heat processes but each type of thermal processes has separate objectives. Therefore, the heat application has been delineated in this unit on basis of the objectives of the heat process after introducing heat exchangers.

2.2 HEAT EXCHANGERS

A heat exchanger is a device that transfers heat from one fluid to another without allowing them to mix, i.e., to transfer heat by the indirect method. In food processing, the purpose is to heat or cool a liquid food in bulk.

The heat exchanger has two channels separated by a partition. Hot water flows through one channel and juice through the other. Heat transfer, in connection with food products, follows general law of heat and, therefore, can be calculated by the formula:

$$Q = UA\,\Delta T$$

Q = Rate of heat transfer (Btu/hr)

U = Overall heat transfer coefficient (Btu hr^{-1} ft^{-2} $^{o}F^{-1}$)

A = Heat transfer area between medium and product (ft^2)

ΔT = Difference in temperature of medium and product (temperature of high medium and temperature of product/ low temperature medium) (^{o}F)

(A true temperature difference is given by logarithm mean difference and is represented by Δ Tm = mean differential temperature.)

From the above equation, it may be said that heat transfer is increased by:

i) Temperature difference between the “warm” and the cold “media”. This is known as driving force;

ii) Greater available surface area – this means that a greater quantity of heat can be transferred if the area of the interface between medium and product is increased;

iii) Greater overall heat transfer coefficient (U Value) – more heat can be transferred if the U value is increased. This value is determined by several factors, including the flow rates of the media, the viscosity of the product, the shape of the heat transfer surface area and the material of which the partitions are made.

2.2.1 Practical Application of Principle of Heat Transfer

We know that food products are sensitive to temperature and agitation and this affects the capacity and efficiency of heat exchangers, for example, the higher temperature difference between the product and the heating medium may cause burning of certain food solids. Some of general principles for practical heat exchangers as outlined by Farrall (1976) are:

i) Rapid movement of the film of fluids on both sides of the heat transfer surface is important.

ii) Thorough and certain mixing of the film adjacent to the heat transfer area, with the body of the fluids is essential.

iii) Make use of the counter flow principle where possible, that is having the cold inlet product adjacent to the coldest outlet of the heating medium in a continuous system.

iv) Use as great a temperature difference as possible consistent with accurate temperature control and prevention of bad effects on the product treated.

v) Use as few intermediate cooling fluids or heating fluids as possible.

vi) Use as thin a sheet of heat transfer wall as possible consistent with proper mechanical strength.

vii) Use a heat transfer surface having good heat conductivity.

2.2.2 Types of Heat Exchangers

There are many types of equipment encountered in the food industry. The most important are the plate type, tubular type, scraped surface and vat type. The heating medium is usually either hot water or steam. A brief description is given below so that we may be able to use them effectively.

I. Tubular heat exchanger

The simplest type of tubular exchangers is the double pipe which consists of two concentric tubes with one fluid passing along the centre tube and the second fluid flowing in the annular space created between the tubes. Triple tube type employs three concentric tubes, with the product flowing through the intermediate passage and the heating or cooling medium flowing with counter current system in the other two passages, so that the product is surrounded on both sides. Today the tubular exchangers are not extensively used in food processing industries. The capital cost for these are low.

II. Scraped surface heat exchanger

The scraped surface heat exchanger is designed for heating and cooling of viscous, sticky and lumping products and for crystallization. This consists of a double-pipe exchanger with a central rotating shaft inside the inner pipe. Scraper blades are attached to the shaft and remove any material which builds up on the inner pipe wall. The second fluid flows in the annular space as in a conventional exchanger. The continual scrapping of the heat transfer surface ensures that higher heat transfer coefficients are obtained with highly viscous fluids.

III. Plate heat exchanger

One of the most popular type of heat exchanger is the plate system in which thin corrugated plates are stacked together to provide passage for the product and for the heating and cooling fluid. The advantages are:

i) High heat transfer surface area within a small plant volume.

ii) High heat transfer coefficients due to configuration of the plate surface.

iii) Easily cleanable either by opening it up or by CIP (cleaning in place) method.

iv) Versatile-addition of extra plates to increase surface area, ability to arrange a wide variety of flow patterns and several different fluids can flow through separate sections of the same heat exchanger, for example, allowing heating, cooling and heat recovery to take place in a simple unit.

v) Comparatively low in cost.

IV. Vat or tank heat exchanger

The flooded jacket, vat or tank is the simplest form of heat-exchanger, which is essentially a tank within a tank, with a space between the two that is flooded with water. The vat types of heat-exchangers are mainly used for batch pasteurization. For heating, a steam injection and mixing unit is employed and the agitator is provided for movement of the product over the heat exchanger surface.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Enlist factors affecting heat transfer.

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2. List the important components of a plate heat exchanger.

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2.3 BLANCHING

As you know that blanching is a heat treatment applied to tissue systems of fruits or vegetables, primarily to inactivate natural food enzymes, prior to canning, freezing or drying. Most blanching operations are accomplished by putting the product in contact with either hot water or steam for an appropriate time. Blanching is not indiscriminate heating. Too little is ineffective, and too much damages the fruits/vegetables. The time is dependent on the objectives of the process, i.e., whether enzymes are to be inactivated or whether partial cooking is desired. It involves: i) heating food to a preset temperature, ii) holding for a preset time, and iii) cool rapidly to ambient temperature. The blanching of vegetables is most often done in hot water or steam containing calcium or magnesium salts to check chlorophyll degradation. Calcium brines or colloidal thickness are used in blanching of fruits for firming them. The blanching is not recommended for frozen fruits after thawing as it results in undesirable changes in texture and flavour. The adequacy of blanching is known through the catalase or the peroxidase test. The peroxidase system is most commonly used and we know that a negative peroxidase test is necessary to prevent the development of undesirable characteristics in the finished product.

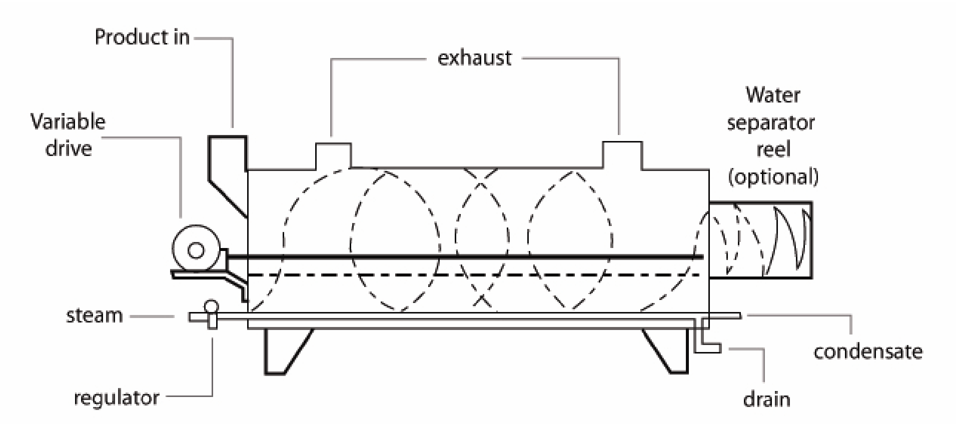
2.3.1 Process Equipment

Rotary hot water and steam blanchers are common process equipment and are shown in Figure 2.1 (a) and (b), respectively. They are available with variable speed drive. The rotary hot water blancher receives the product through a valve just above the drive end. The product is conducted into a spiral unit which conveys it to the opposite end. In the case of the hooded live steam blancher which has a perforated wire belt, the blancher serves as a conveyor making it very adoptable to the system.

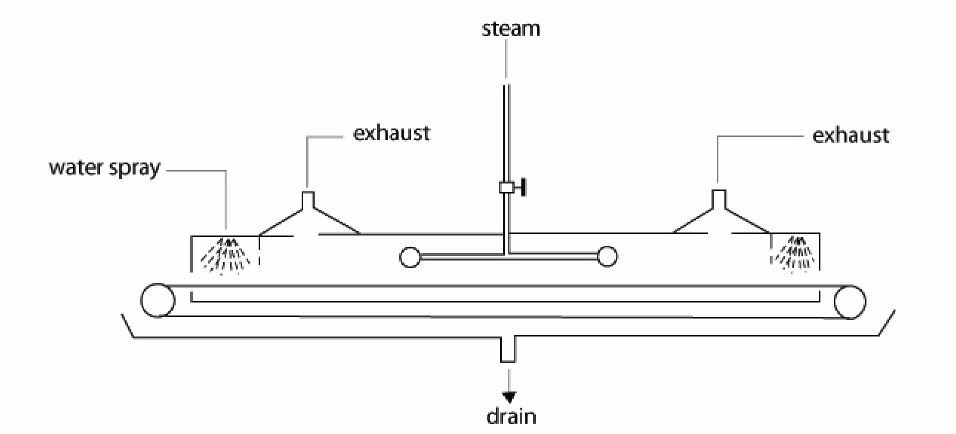
The steam blancher consists of a metal frame with galvanized sheet metal forming the steam chamber. The unit is frequently equipped with both water and steam sprays to increase its versatility as a scolder/blancher. The lower belt of the hooded chamber is pitched to a separate drain outlet for removal of condensate. A typical commercial steam blancher is approximately 20 ft. long, 4 ft. wide and 4 ft. high. A typical water blancher would be around 6 ft. in height with an overall length of 21 ft. In general steam blanching results in greater retention of water-soluble nutrients due to less leaching loss. With leafy vegetables, such as spinach, care must be taken not to overload the belt since upon heating these products tend to wet and mat. Heat transfer through this mat is very slow and under blanching could occur.

The advantages of steam blanchers are: smaller loss of water soluble components, smaller volume of waste, lower disposal charges and easy to clean and sterilize. The disadvantages associated with a steam blanchers are: limited cleaning of food, higher capital cost, uneven blanching, some mass loss in food and poor energy efficiency. At the same time, the advantages of hot water blanchers are lower capital cost and better energy efficiency. The disadvantages are loss of water soluble components, higher cost of water and disposal of effluent and risk of contamination.

A thermal screw may also be used to steam blanch products. Here, the product is conveyed in a trough by a closely fitting helical screw. Steam injected at regular interval is used to heat the product. Similar designs use hot water as the transfer medium, and this reduces abrasion and damage to sensitive products such as mushroom.



(a)



(b)

Figure 2.1: Blanchers. a) Water type rotary blancher; b) steam blancher for leafy products

We should select a size of blancher which will handle the line capacity without being over crowded. Do you know that one of the serious mistakes made by the operator is overloading. As an operator, we have to ensure maintenance of the unit on a regular basis and check that automatic controls are performing well. The use of a check thermometer to ascertain the accuracy of the one installed on the unit is a good practice.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Draw a diagram of water type rotary blancher.

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2. What are the advantages of steam blancher?

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2.4 PASTEURIZATION

Pasteurization is the term usually applied to preservation of liquid products like pulps or juices by heat. We know that this thermal treatment primarily inactivates the disease causing microorganisms present in the foods. The process i) kills non-spore forming bacteria, ii) inactivates enzymes, and iii) destroys yeasts and moulds. It is suitable for short time preservation because it reduces the number of fermentative microorganisms that contribute to the acidification of juice, at the expense of sugars. The processing details have already been discussed in earlier units and we know that the time-temperature treatment depends on i) the heat resistance of the particular vegetative or pathogenic organism, and ii) the sensitivity of product quality to heat.

2.4.1 Process Equipment

Since pasteurization is normally done at temperature less than 100° C, solid food particles can be pasteurized in the same type of equipment as that used for blanching. A water bath is the simplest pasteurization equipment for acid food products. Packaged food products are placed in steel tanks for heating with hot water. At the end of process cold water is added for cooling. A continuous water bath pasteurizer is used in pickle industry and in fruit processing. The equipment consists of a long tank through which the product moves on a belt.

Continuous water spray equipment is used for pasteurizing fruit juices. In this unit, the product is conveyed on a belt through several temperature zones where water is sprayed onto the containers. The zones are first pre-heat, second pre-heat, pasteurization, pre-cool and final cool. Do remember that glass containers be processed with care to avoid thermal shock.

For fruit, fruit juices, and tomatoes, the continuous, agitating, atmospheric cooker is widely used. Operation of the unit is similar to the continuous, agitating, pressure cooker wherein the cans are screw conveyed through the unit. The unit operates at atmospheric pressure with either steam, hot water, or a combination of steam and hot water as the heating medium. Processing rates of up to 20-250 cans/minute can be achieved.

Pasteurization of unpackaged liquid is commonly done in indirect heat exchanger and High Temperature Short Time (HTST) processing is preferred for high throughputs (Figure 2.2). The nutrient loss is less. This procedure makes use of a plate heat exchanger with three sections for heating, regeneration, and cooling, respectively, a holding tube to pasteurization temperature for the required time and a flow diversion value to ensure that liquid which has not reached the desired temperature is not discharged as finished product. It is important to ensure that rapid cooling occurs in order to prevent quality deterioration and to ensure a uniform residence time. The temperature time treatment for some of the food products is given in Table 2.1.

Table 2.1: Temperature/time treatment in pasteurization

Food Product	Temp (°C)	Time (Seconds)
Milk	72	15
Tomato Juice	118	60
Fruit Juice	88	15
Soft Drink	95	10

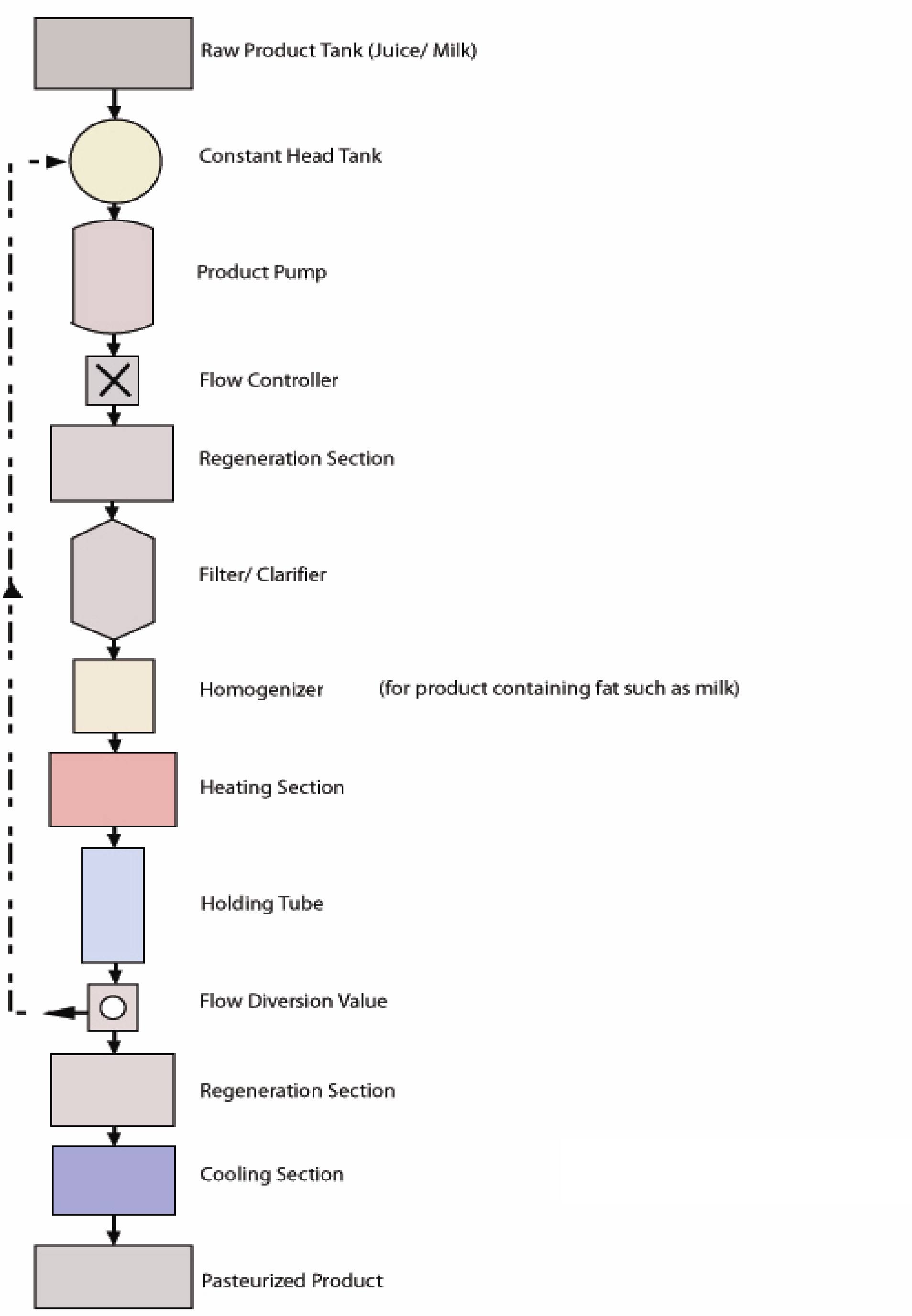

Figure 2.2: Flow diagram of pasteurization process

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Draw a line diagram of HTST pasteurization.

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2. Write pasteurization temperature and time combination for fruit juice and tomato juice.

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2.5 STERILIZATION

Sterilizing a product means exposing it to sufficiently high temperature and for a sufficiently long time that may kill all micro-organisms. In contrast to pasteurization, commercial sterilization is intended to give long shelf life (in excess of six months) to foods by destroying both microbial and enzyme activities. The products that are difficult to sterilize are low in acid and often high in protein and contain spore bearing bacteria. Sometimes severe heat treatment results in substantial changes in nutritional and sensory qualities of food. Therefore, optimum time temperature schedules are to be worked out for each product for better quality and shelf life. Sterilized products have excellent keeping quality.

There are two basic methods for sterilization (i) heating the food after it has been placed in a container (known as "in-container"), and (ii) heating and cooling the food and then packaging it aseptically (aseptic packaging). This subsection deals about sterilization process. The traditional retorting of canned foods is an example of sterilization process.

2.5.1 Process Equipment

The Batch Retort: The batch operated retorts are either horizontal or vertical. The basic feature of a vertical retort is given in Figure 2.3. It consists of a pressure vessel, usually cylindrical and a basket or grate into which individual cans are placed. The various layers of cans are separated by grids which allow thorough circulation of steam. The retort is supplied with steam, cold water and compressed air. Inlets are fitted with globe valves and the outer outlets with gate valves. At the bottom of the retort, a steam spreader is connected to the steam inlet to ensure uniform distribution of stream inside the retort. The drain is fitted to the base of the retort to remove the condensate during heating and cooling cycles. A vent, with a valve, is provided on the body of the retort. It is intended to purge the air flow between the cans during the initial part of the come-up period. The retort instrument packet is fitted with a petcock which acts as a permanent bleeder; mercury in glass thermometer; an additional place for a check thermometer; a temperature-sensing probe connecting to the recording thermometer; and a pressure gauge. An additional petcock and a pressure safety valve are on the lid. The retorts are strong enough to withstand the pressure of air, besides that of steam pressure, i.e., a working pressure of 2.8-3.5 kg/cm^2 (40-50 psig). The retorts should be located in a sufficiently large area to enable easy operation. The floor should be resistant to wear, well-drained, and impervious to water. The free space between the retort should be at least 50 cm.

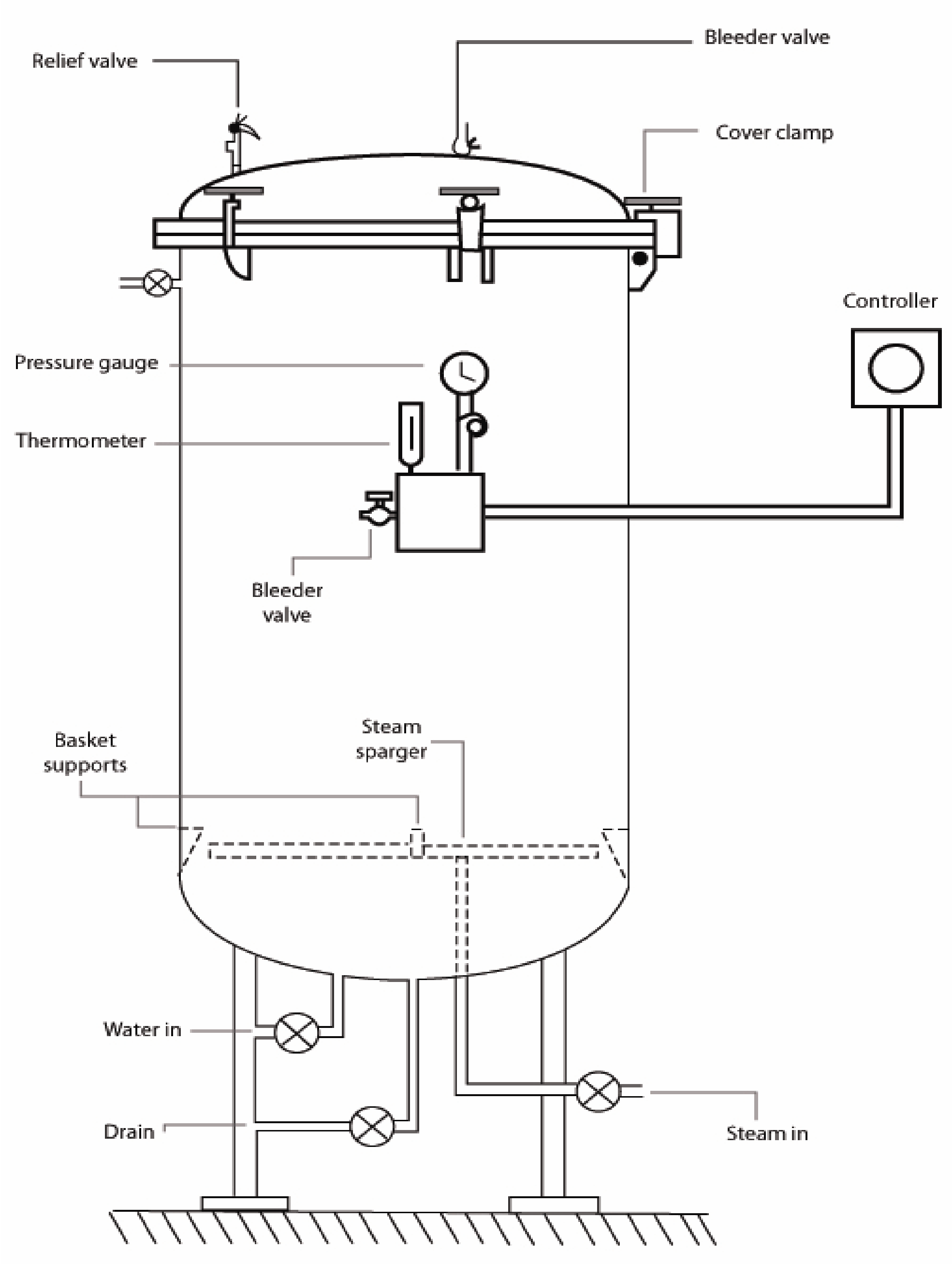

Figure 2.3: Basic layout for a vertical retort

Steam is an excellent heat medium because of its ability to condense on container surface releasing large amounts of latent heat. The main enemy of efficient heating in a closed vessel (e.g. a retort) using saturated steam is the presence of entrapped air especially that trapped in the small spaces between containers in the load. The presence of air reduces the temperature and tends to insulate the cans giving lower rates of heat transfer. This means that in order to bring about efficient and uniform heating, air must be purged, or as it is, referred to in the industry 'venting' from the retort at the start of the process. This is achieved by introducing high velocity steam into the retort. The rotary retorts ensure agitation and give adequate heating and acceptable processing times.

Retort operation is a specialized job. As a technician, you should be well trained in its operation and ensure proper processing. The basic operating procedure is as follows: The cans are placed in a basket which is lowered into the retort and then steam is introduced. Time is allowed for any condensed water to drain away before a drain valve at the base of the retort is closed.

Acidic products, for example canned fruits, require a milder heat treatment and use steam at atmospheric temperature, while the high temperature is required for less acidic foods and need heat to be supplied by steam at pressures greater than atmosphere. The steam is introduced at high speed for venting. After a short period, the vent valve is closed and the retort is brought up to temperature by allowing the steam pressure to rise to a pre-set level. After processing for the required time, the steam flow is stopped and the cooling water flow is started. As the temperature of the can's content rises the vapour pressure inside the can increases. During the heating cycle increase in pressure is balanced by the steam pressure outside the can, however, during the cooling cycle this internal pressure is balanced by admitting compressed air simultaneously. Cooling continues in retort until the temperature falls to about 40°C after which retort is opened and the cans are removed.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Draw a labelled diagram of a Vertical Retort.

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2. What is venting?

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2.6 ASEPTIC PROCESSING AND PACKAGING

Aseptic processing and packaging is a remarkable technological advancement over traditional retort processing. It is the process by which micro-organisms are prevented from entering into the package during and after packaging. It is achieved by filling a sterilized package with a sterile food product within the confines of a hygienic environment. The packaged product could be stored without the need for refrigeration or preservatives for periods up to one year. Aseptically packaged products include milk, juices, tomato soups, sauces, broths, soy beverages, etc. The production of these products is constantly increasing in the country.

2.6.1 The Aseptic Process

The aseptic process is a technique for processing liquid food products by exposing them to brief intense heating. Sterility is the key word in the process and involves the same principles as discussed with respect to sterilization. Since very high temperatures are employed (125 °C to 145 °C), the process is also referred to as Ultra High Temperature (UHT). The holding time of the product at high temperature is very short (3 to 15 seconds) and therefore, thermal stress on the product is less while ensuring safety. This rapid heating and cooling process also reduces the energy use and nutrient losses associated with conventional sterilization. Processing at high temperature usually requires that the process be based on enzyme inactivation rather than microbial destruction. The process involves:

i) Sterilization of the product in sterile equipment;
ii) Pre-sterilized containers;
iii) Aseptic environment for filling of the sterile product into the sterile package; and
iv) Sterile packaging.

The advantages of the UHT processing are (i) higher quality (ii) increased shelf life (iii) easy adaptability to many size containers from single serving (200 ml.) to thousands of litres of bulk pack, and (iv) cheaper packaging material. The disadvantages are (i) higher cost (ii) sophisticated control and maintenance of plant, and (iii) higher skill level on the part of operators and maintenance personnel.

2.6.2 Process Equipment

UHT plants are often designed with great product flexibility in order to enable processing of a wide range of products in the same plant. Both low acid products (with pH values above 4.5) and high acid products (with pH values below 4.5) can be treated in UHT plant. However, only low acid products require UHT treatment in order to become commercially sterile as spores can grow in a low acid environment. Spores cannot develop in high acid products such as juice and the heat treatment is, therefore, only intended to kill yeasts and moulds. Normal high-temperature pasteurization is sufficient to make high end products commercially sterile. The UHT plants are classified according to the method of heating. The options are consolidated in Table 2.2.

Table 2.2: Types of UHT plants

Sl. No	Type of plant	Options available
1.	Direct Heating (Product and the heating media are in direct contact)	Steam injection (steam into product) Steam infusion (product into steam)
2.	Indirect Heating (Heat transfer surface between the product and the heating media)	▪ Plate, ▪ Tubular and ▪ Scraped surface heat exchangers

i) **Direct Heating:** There are two main methods for aseptic processing by direct methods: by injecting pressurized steam into product or by injecting product into steam (steam infusion). Both systems work on the principle that the steam comes into contact with the product, it will condense and give up some latent heat causing the product to heat up very quickly. The steam has to be of satisfactory quality, i.e., derived from drinking water. Simplified flow sheets for direct steam injection and steam infusion are shown in Figure 2.4 and 2.5, respectively. The basic principle for both systems is to pass the product from a balance tank to a pre-heating and final heating system, usually by a plate heat exchanger at 75-80°C. The product then passes through the main product pump to the steam injection or infusion system. The mixture then flows through a holding tube (2-4 seconds) which enters tangentially into the vacuum chamber. The product passes on an aseptic path – pump, homogenizer, cooler and storage tank – to aseptic package. Steam injection is most suitable for low viscosity homogeneous products such as milk and juice. Steam infusion is for more gentler and sensitive products.

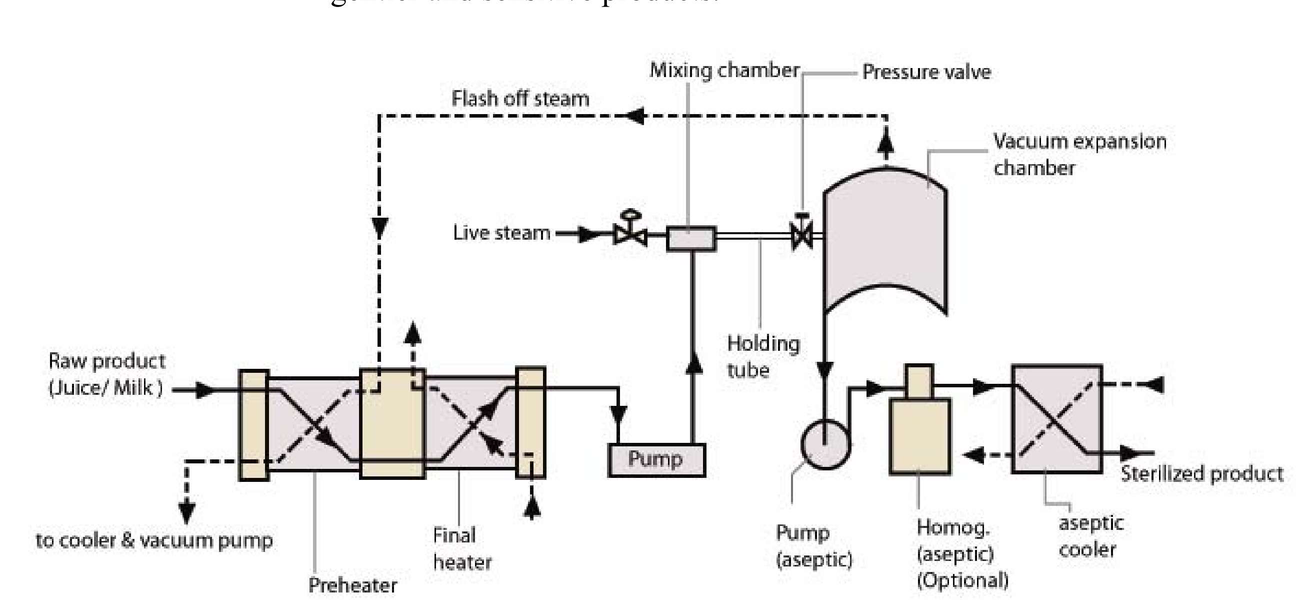

Figure 2.4: Diagram of an ultra-high temperature heating plant using direct heating (steam injection)

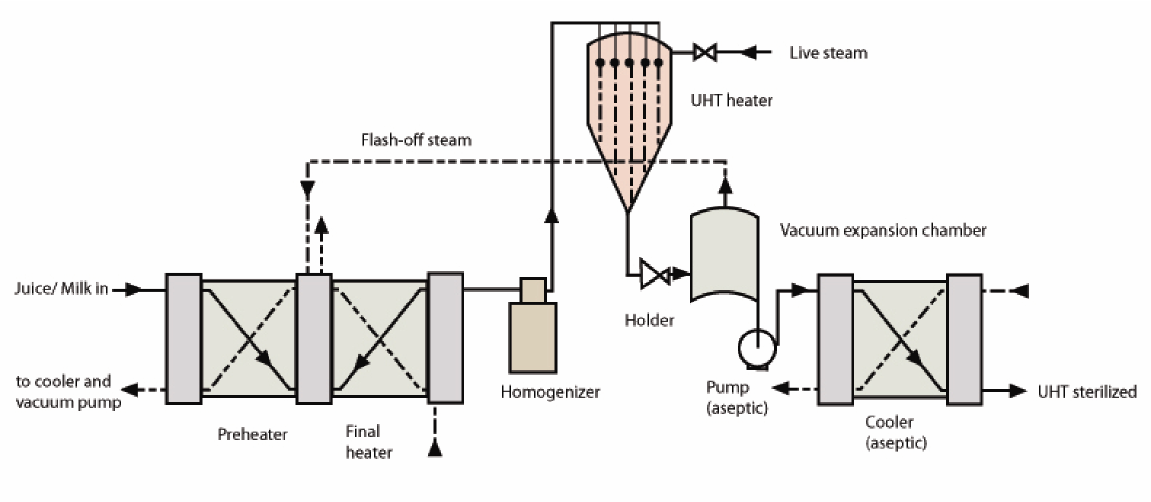

Figure 2.5: Diagram of a UHT plant using direct heating of product in a steam space (steam infusion)

ii) Indirect UHT Plant: UHT heating plants using indirect heating method rely on having a heat transfer surface between the product and the heating media. There are three main types of indirect heating system, viz. plate heat exchanger, tubular heat exchanger and scraped surface heat exchanger. Each system has benefits as well as drawbacks depending on the product process requirement. A simplified flow sheet for an indirect UHT plant is shown in Figure 2.6. UHT plants of the indirect heating types are built for capacities up to 30,000 l/h.

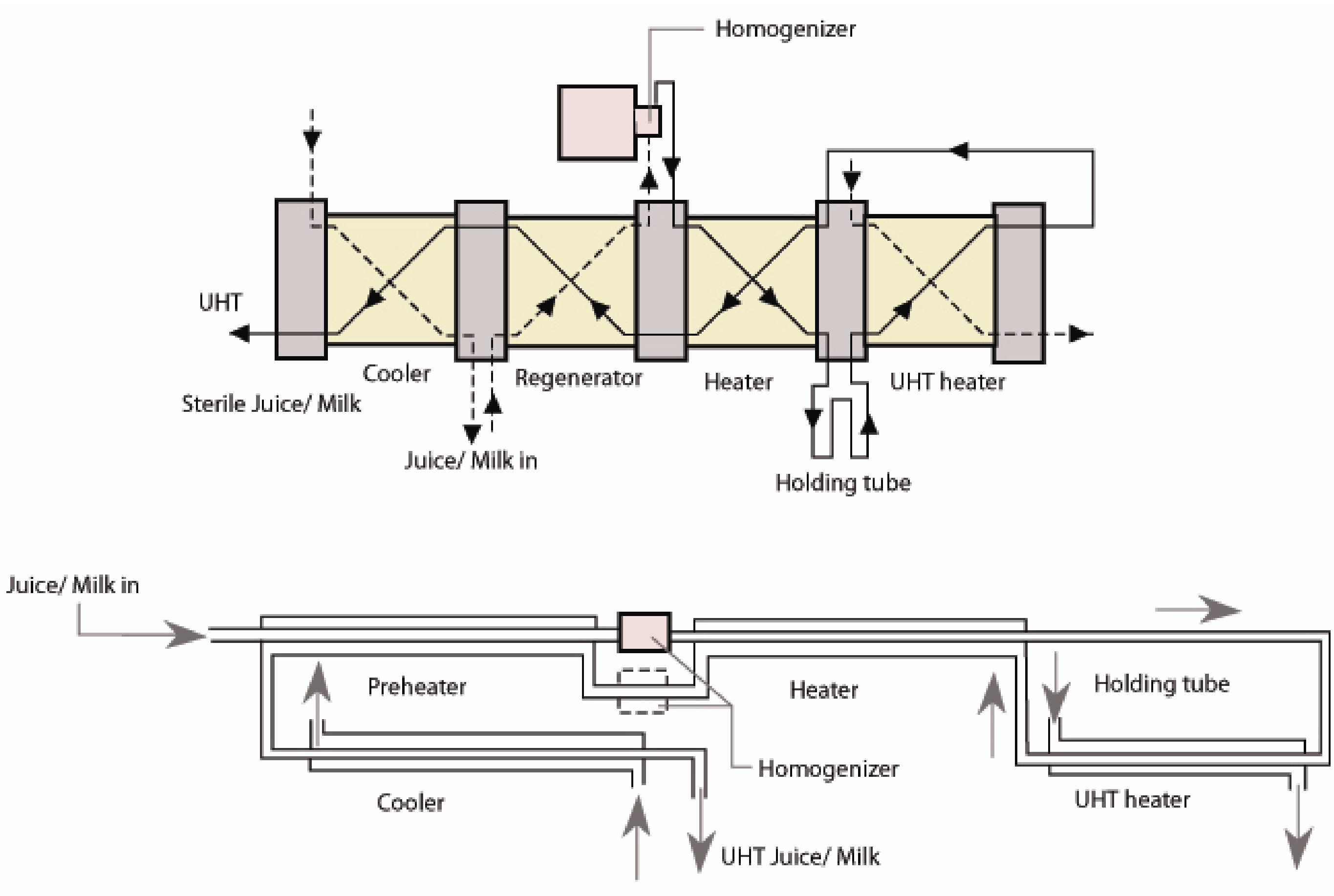

Figure 2.6: Diagrammatic representation of UHT heating plants using indirect heating methods

2.6.3 Aseptic Packages

There are several different forms of packages that are used in aseptic processing such as cans, laminates, flexible pouches, thermoformed plastic containers, tetrapack, etc. Tetrapack, a revolutionary package, is a laminate of three materials: high-quality paperboard, polyethylene and aluminium. Each material plays a critical role in achieving the unique benefits of the aseptic package. Paper (70%) provides stiffness, strength and the efficient brick shape to the package. Polyethylene (24%) on the innermost layer forms the seals that make the package liquid-tight. A protective coating on the exterior keeps the package dry. Aluminium (6%) is the silver material we see on the inside of the aseptic package. This ultra-thin layer of foil forms a barrier against light and oxygen, eliminating the need for refrigeration and preventing spoilage without using preservatives. The aseptic package contains a total of six layers in this order: polyethylene, paper, polyethylene, aluminium foil, polyethylene and polyethylene. The processing steps involved in formation of a package are: sterilization of roll and, formation of package, filling and sealing in sterile environment.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the advantages of UHT Processing?

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2. Draw a line diagram of the direct UHT steam injection plant.

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3. Enlist the packaging materials forming the common aseptic package.

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2.7 HOT PACK OR HOT FILL

The terms Hot Pack or Hot Fill or Hot-Fill-Hold-Cool Process or Flash Pasteurization refer to the filling of previously pasteurized or sterilized foods, while still hot, into clean but not necessarily sterile containers, under clean but not necessarily aseptic conditions. The hermetically sealed containers are then inverted and held for an adequate time (1-3 minutes) to sterilize the lid as well as the containers. The hot-filled containers are then cooled either in a water-spray tunnel or by immersing in a tank containing chlorinated cold water. Rapid cooling is essential to retain the colour, flavour and nutrients. In yet another practice followed in some western countries, the head space is flushed with steam or nitrogen to minimize the residual oxygen. A schematic diagram of hot-fill system is shown in Figure 2.7.

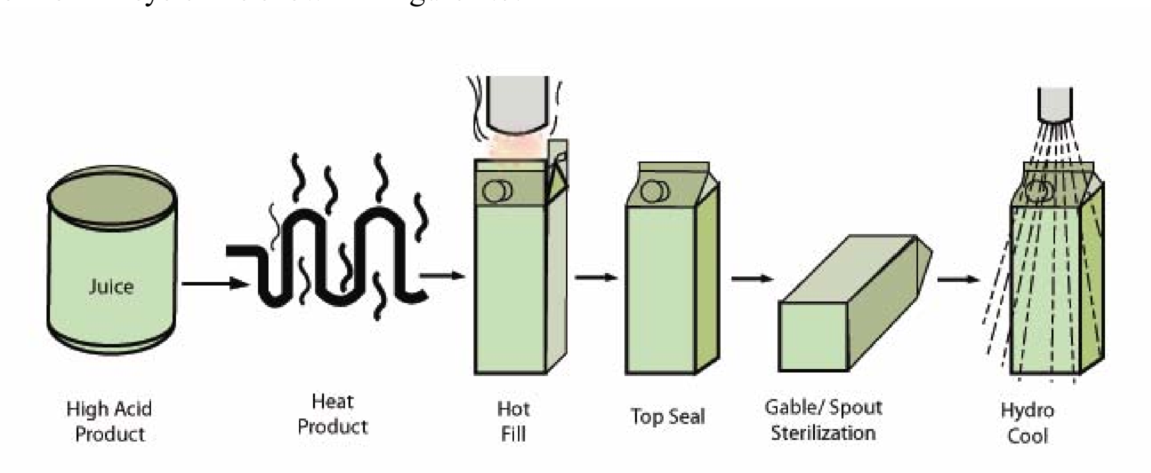

Figure 2.7: Hot-fill system – A schematic diagram

Hot-pack is more effective with acid foods, as at pH below 4.5 *Clostridium botulinum* will not grow or produce toxin. Hot pack with low acid foods (above pH 4.5) is not possible unless the product is recognized as being only pasteurized and will be stored under refrigeration. However, hot pack treatment could be combined with some additional means of preservation such as very high sugar content. The temperature and time for pasteurization and hot filling depend upon the specific product's pH and other food characteristics. It is essential that the definite temperature and time must be adhered for hot pack processing to be effective.

Check Your Progress Exercise 6

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand by Hot Pack or Hot Fill Process?

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2. Draw a schematic diagram of hot-fill process.

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2.8 MICROWAVE AND OHMIC HEATING

We are familiar with microwave ovens, their use and popularity is increasing constantly. In microwave heating, a high frequency field is passed through the food, stimulating the vibrational frequencies of chemical bonds to heat the material. Microwave and ohmic heating are known as heat generation methods where heat is generated by the material *in situ* as a result of interaction with an external field.

2.8.1 Microwave Heating

Microwaves are electromagnetic waves of radiant energy, differing from such other electromagnetic radiations as light waves and radio waves primarily in wavelength and frequency. The microwave frequency ranges from 300 MHz. to 300 GHz. corresponding to wavelength in the range of 0.001-1 m, and is positioned somewhat close to FM radio and television broadcasting brands. Microwaves, like light, travel in straight lines. They are reflected by metals, pass through air and many, but not all types of glass, paper and plastic materials, and are absorbed by several food constituents including water.

When microwaves pass into foods, water molecules and other polar molecules tend to align themselves with the electric field. But the electric field reverses 915 or 2450 million times per second (MHz.). The molecules attempting to oscillate at such frequencies generate intermolecular friction which quickly causes the food to heat. In microwave, heat is generated quickly and quite uniformly throughout the mass. .

The use of microwave energy in food processing can be classified into six unit operations: heating, baking and (pre) cooking, tempering, blanching, pasteurization and sterilization, and dehydration.

The most commonly used type of microwave generator is an electronic device called a magnetron. A magnetron is a kind of electron tube within a magnetic field which propagates high frequency radiant energy. The microwave field is transmitted to the oven cavity / tunnel via an antenna placed inside the wave guide. Industrial oven is either a larger version of the domestic oven and is used for batch processing (e.g. tempering) or for continuous processes, taking the form of tunnel with food conveyed on belt inside an enclosure.

A major use of microwave in the food industry is tempering and thawing of frozen foods, especially meat, fish, butter and fruit. Tempering raises the temperature of frozen foods to around – 4°C and thus allows other operations such as cutting to be carried out much faster. Microwave tempering has a number of advantages over conventional methods as it takes minutes rather than days, reduces labour costs and requires a smaller space than the conventional refrigerated storage room. Microwaves have been used for pasteurization of ready meals, further developments are needed to use them in commercial sterilization.

2.8.2 Ohmic Heating

In ohmic heating, an electric current is passed through a food material which then heats as a result of its inherent electrical resistance. The process involves the passage of low frequency alternating current (50 or 60 Hz.) through the product. The electrical energy is transformed into thermal energy. The extent of heating depends on the uniformity of the electrical conduction throughout the product and its residence time in the heater. A typical layout of an aseptic processing system using ohmic heaters is shown in Figure 2.8.

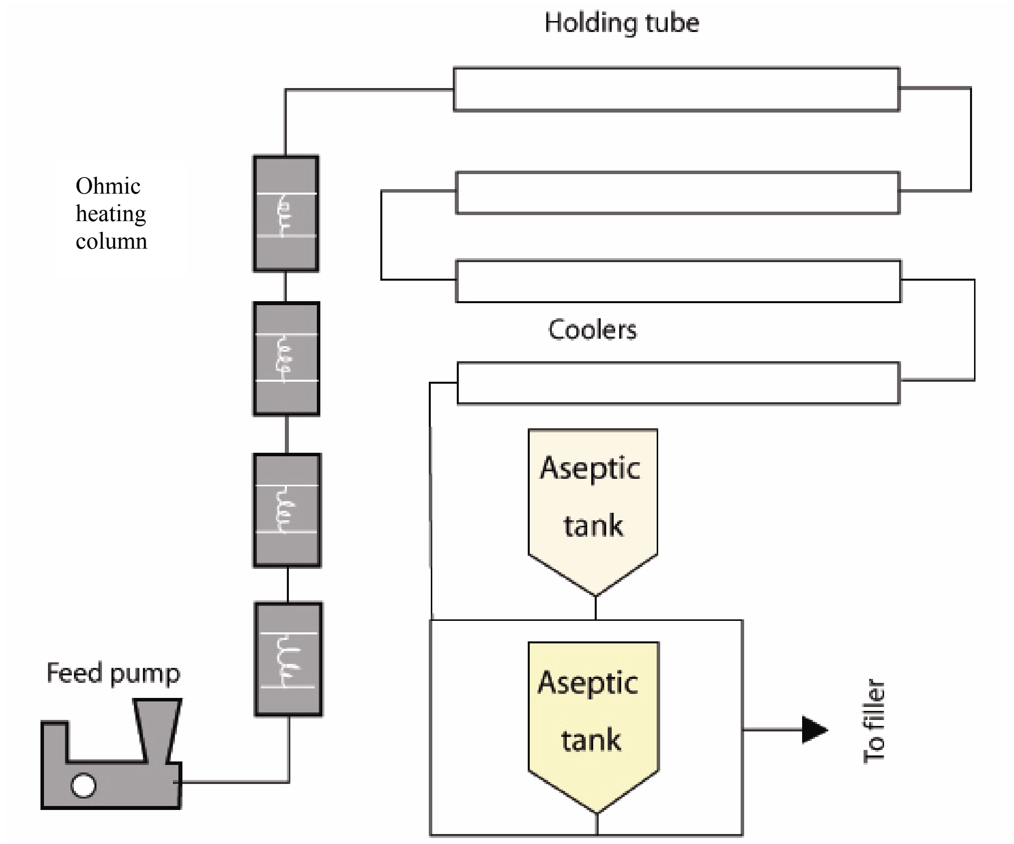

Figure 2.8: Schematic diagram of a continuous-flow ohmic heating process

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Check Your Progress Exercise 7

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State the principle of microwave heating and its major use in food industry.

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2. What is ohmic heating?

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2.9 LET US SUM UP

The principles of heat transfer are widely used in food processing industries. The common processes based on heat application are blanching, pasteurization, sterilization and aseptic processing. The types of heat exchangers used in these processes may include plate, vat, tubular or scraped surface. Plate heat exchangers are quite common due to various advantages such as high heat transfer surface area within a small plant volume, high heat transfer coefficient, versatility, and low cost.

Rotary hot water and steam blanchers are commonly used equipment for blanching, and size of the blancher should be in proportion to line capacity of the plant. Plate heat exchangers are usually employed for pasteurization of unpackaged liquid. The raw product passes through regeneration, heating, holding and cooling sections. After heating and holding to a stipulated temperature-time combination, the pasteurized product is chilled immediately through regeneration and cooling section. Sterilization is more severe heat treatment employed to have longer shelf life (in excess of six months) of food products and the traditional retorting of canned foods is an example of sterilization process. The entrapped air should be vented from the retort at the start of process for efficient and uniform heating. Aseptic processing and packaging is a technological advancement wherein sterilization is obtained by employing Ultra High Temperature (UHT) (125° C to 145° C) for very short time. The UHT plants could be (i) direct steam injection, (ii) direct steam infusion, and (iii) indirect UHT plant with plate/tubular/scraped surface heat exchanger. Hot pack or hot fill, effective with acid foods, involves filling of previously pasteurized or sterilized foods, while still hot into clean containers.

The new techniques microwave and ohmic heating are known as heat generation methods where heat is generated by the material *in situ* as a result of interaction with an external field.

2.10 KEY WORDS

Aseptic packaging : It is a process by which micro-organisms are prevented from entering into the package during and after packaging. An aseptic process is achieved by filling a sterilized package with a sterile food product within the confines of a hygienic environment.

Blanching : Blanching is a heat treatment applied to tissue systems of fruits or vegetables primarily to

		inactive natural food enzymes prior to canning, freezing and drying.
Commercially sterile	:	The terms are used wherein all pathogenic and toxin forming organisms have been destroyed in the product.
Heat exchanger	:	A device that transfers heat from one fluid to another without allowing them to mix.
Pasteurisation	:	A form of thermal processing, which uses moderate degree of heat treatment generally at temperatures below the boiling point of water, for short time preservation. It inactivates bacteria and disease producing organisms of importance in specific food stuff.
Sterilisation	:	Complete destruction of micro-organisms by powerful heat treatment.
UHT	:	Ultra High Temperature (UHT) is a technique for processing liquid food products by exposing them to intensive heating for a short time.

2.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer may include the following points:

1. • Temperature difference between heating and cooling media
   • Surface area for heat transfer
   • Heat transfer coefficient

2. Important components of plate heat exchangers: Head frame, guide bar, follower, end support, carrying bar, hinged distance piece, tightening screw device, detachable ratchet spanner, bank of plates, connector grid with inlet and outlet bosses.

Check Your Progress Exercise 2

Your answer may include the following points:

1. Please refer Figure 2.1a.

2. • Smaller loss of water soluble components
   • Smaller volume of waste
   • Lower disposal charges
   • Easy to clean and sterilize

Check Your Progress Exercise3

Your answer may include the following points:

1. Please refer Figure 2.2.
2. Fruit Juice –88°C / 15 seconds
   Tomato Juice –118°C / 60 seconds

Check Your Progress Exercise 4

Your answer may include the following points:

1. Please refer Figure 2.3.

2.
   - Entrapped air tends to insulate the cans and gives lower rates of heat transfer.
   - Air is purged out from the retort at the start of process for uniform heating. This is achieved by introducing high velocity steam into the retort.

Check Your Progress Exercise 5

Your answer may include the following points:

1.
   - Higher product quality
   - Increased shelf life
   - Easily adaptable to many size containers

2. Please refer Figure 2.4.

3. The aseptic package laminate consists of (a) paper board, (b) polyethylene, and (c) aluminium.

Check Your Progress Exercise 6

Your answer may include the following points:

1. The process includes rapidly heating the juice in a heat exchanger and filling containers with the hot juice (around 95°C) followed by sealing and inverting, thus pasteurizing the container. It should be followed by rapid cooling.

2. Please refer Figure 2.6.

Check Your Progress Exercise 7

Your answers should include the following points:

1. A magnetron in the oven generates electromagnetic waves (microwave). In the electromagnetic field generated in the oven, there is a rapid reversal of change (at either 915 or 2450 mega hertz). When microwaves penetrate a food, the dipolar molecules of water that are present oscillate about their axes in response to this reversal of change. Heat is generated in the food itself as a result of rapid oscillation.

The major use of microwave in the food industry is tempering and thawing of frozen foods.

2. The ohmic heating is a process where heat is generated in the product by passing an electric current. The heat is produced due to resistance created by the product during passage of current.

2.12 SOME USEFUL BOOKS

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UNIT 3 CANNING OF FRUITS AND VEGETABLES

Structure

3.0 OBJECTIVES

After reading this unit, you should be able to:

- state the principles of canning;
- explain the various unit operations involved in canning;
- describe the canning process of fruits and vegetables; and
- list the cans and types of spoilages of canned products.

3.1 INTRODUCTION

You know there are several methods of preservation of fruits and vegetables and canning is one of them. It is an important method of food preservation by heat. In this process, the foodstuff (fruits & vegetables) are placed in containers, and sterilized by placing them in hot water or steam. Canning is also known as appertizing in honour of its inventor. In 1804, Nicholas Appert, a confectioner in France, invented a process of sealing foods hermetically in containers and sterilizing them by heat. He had also published a book entitled, "The Art of Preserving Animal and Vegetable Substance for Many Years", which is the first known work on modern canning.

Canning is an important process of preservation of fruits and vegetables by application of heat. In this unit, we will discuss canning process for fruits and vegetables. Several unit operations are involved in the canning process. The process discusses the principles and purpose of canning, types and causes of spoilages. Tin cans are used in the canning of fruits and vegetables.

Fruits and vegetables are canned in the season when the raw material is available in plenty and at low price. The canned products are sold round the year and give better returns to the grower. Thus, canning of fruits and vegetables is an important industry.

3.2 CANNING PROCESS FOR FRUITS AND VEGETABLES

Canning is defined as the preservation of foods in the sealed containers and usually implies heat treatment as the principal factor in prevention of spoilage. Mostly the canning is done in tin cans but other containers like glass, plastics, etc. The fruits and vegetables used for canning should be as fresh as possible so that their quality could be retained. Fruits should be mature, firm ripe and free from all defects, while vegetables should be usually tender.

3.2.1 Principles

1. Destruction of spoilage organisms within the sealed containers by application of heat,
2. To improve the texture, flavour and appearance by cooking, and
3. To stop recontamination of food during storage.

You should be careful during heat application that palatability of food is least disturbed while all the microbial load is destroyed.

3.2.2 Process

Canning process includes the following steps or unit operations:

Selection of fruits & vegetables → Sorting & Grading → Washing → Peeling → Cutting → Blanching → Filling → Syruping/Brining → Lidding or Clinching → Exhausting → Seaming → Processing → Cooling → Testing for defects → Storage.

i) Selection of Fruits and Vegetables

We should select the fresh good quality fruits and vegetables for canning because quality of canned product is dependent on the quality of raw material. Fruits should be firm, mature and uniformly ripe. Over-ripe, insect infected and diseased fruits and vegetables should be rejected. Unripe and immature fruits should be rejected because they generally shrivel and toughened on canning. Vegetables should be tender. Fruits and vegetables should be free of dirt.

ii) Sorting and Grading

We should see that any spoiled, blemished, injured fruit or vegetable be discarded. Raw material should be sorted based on maturity and ripeness. Fruit and vegetables should be graded according to size and colour to obtain uniform quality of canned product. Grading can be done by hand or by machines. Screw type and roller type grader are generally used.

Fruits like berries, cherries, grape and plum are graded whole, while peach, pear, apricot, mango, pineapple, etc., are generally graded after cutting into pieces.

iii) Washing

Fruits and vegetables should be washed with water thoroughly. Washing will remove dust, dirt and any sprayed chemical residue. Any microorganism over the surface of the fruits or vegetables are also washed out. Water used for washing may be cold or hot. We may employ chlorine (150ppm) or potassium permanganate (dilute solution) in water to disinfect fruits and vegetables. Fruits and vegetables are generally soaked in water tank before washing by hand. They can be washed by spraying water, which is the most effective method.

iv) Peeling

Washed fruits and vegetables are prepared for canning. The fruits and vegetables are peeled by hand with knife or machine, heat treatment or lye solution. Lye is a solution of caustic soda. For example, peaches and potatoes are scaled in steam or boiling water and put in cold water to soften and loosen or cracking of skin. Later the skin can easily be removed by hand or pressure spray of water.

In case of lye peeling of fruits and vegetables, e.g., peaches, apricots, orange and sweet potatoes are dipped in boiling lye (1-2% caustic soda) for ½ to 2 minutes. Any trace of alkali is removed by washing fruits and vegetables in running cold water; sometimes they are also washed in water containing 0.5 per cent citric acid or hydrochloric acid.

v) Cutting

We should cut the fruits and vegetables depending upon the requirement like slice, dice, finger etc either by knife or by machine. At the same time seed, stone and core are also removed by special coring knife.

vi) Blanching

In blanching operations the prepared fruits and vegetables are kept in boiling water or exposed to steam for 2 to 5 minutes followed by cooling in running cold water. The time and temperature of blanching vary depending on the type of raw material. Inactivation of peroxidase enzyme is used as an index adequacy of blanching. The purposes of blanching are: (1) to inactivate the enzymes, which cause discolouration and off-flavour, (2) to reduce the volume by shrinkage, making their packing easier, (3) to reduce the microbial load on raw materials, (4) to enhance the green colour of vegetables like peas and spinach, (5) to remove undesirable acids and astringent taste of the peel resulting improved flavour, and (6) to remove occluded gases for reducing strain on the seam of can during processing.

vii) Filling

Tin cans are used as containers for canning. The cans can be opened from any end as they are called open top sanitary can. Cans are washed with hot water. Prepared fruits and vegetables are filled into cans either by hand or by machine. Plain cans are used generally, although in case of coloured fruits like black grapes, red plum, strawberries, etc., lacquered cans are employed.

In case of canned fruits the drained weight should not be less than 50% and for berry fruits not less than 40%. Similarly for canned vegetables the drained weight should not be less than 55% but in case of tomatoes limit is the 50%. Therefore, fruits and vegetables are filled about 60 per cent of the filling capacity of a can.

viii) Syruping

A solution of sugar in water is called syrup. Generally the fruits are covered with sugar syrup. Cans are filled with hot (79°–82°C) sugar syrup, leaving a headspace of 0.3 to 0.5cm. Syrup of 10° to 55° Brix (per cent sucrose) is generally used. We can prepare sugar syrup of 20° Brix by dissolving 250 g sugar in one-liter water and of 50^{o}Brix by dissolving one kg of sugar in one litre water. Sometimes citric acid and ascorbic acid are also mixed with the syrup to improve flavour and nutritional value, respectively. The purpose of adding syrup to fruits is (1) to improve taste, (2) to fill up the interspaces in can, and (3) to facilitate further processing.

ix) Brining

Brine is a solution of common salt in water. Brine is used in canning of vegetables. A brine of 1 to 3% salt is used at 79°-82°C, leaving a headspace of 0.3 to 0.5 cm in the can. The objectives of brining are to improve the taste of vegetables and to facilitate further processing by filling the interspaces of vegetables in the can.

x) Lidding or Clinching

Now the filled cans are covered loosely with the lid before exhausting. It has some disadvantages such as spilling of the contents and toppling of the lids. In modern canning, lidding has been replaced by clinching operation. In this case, lid is partially seamed. The lid remains sufficiently loose to permit the escape of gases, air and vapour formed during exhausting operation.

xi) Exhausting

There are respiratory gases and air remain in the cans, which are to be removed before processing. The method of removing these gases is known as exhausting. Containers are exhausted by heating or mechanically. In heat exhausting, the cans are passed through a tank of hot water or exhaust box under steam. The fruit cans are exhausted at 82 to 100°C for 7-10 minutes or until temperature at the centre of the can reaches 74°C. The vegetable cans are exhausted at 90 to 100°C for 7-10 minutes or until temperature at the centre of the can reaches 77°C. The proper exhausting reduces the strain on the seam of the can.

The time and temperature of exhausting vary with the size and contents of can, but it should be sufficient to ensure a vacuum of 12 to 15 inch Hg in processed and cooled can.

xii) Sealing or Seaming

After exhausting, the cans are sealed by double seaming machine and the method is called seaming. In sealing lids on cans, a double seam is created, and the method of sealing or closing is also known as seaming.

xiii) Processing

Process of heating and cooling of canned food to inactivate bacteria and to preserve food is also called as commercial sterilization. Many bacterial spores are heat resistant, which can only be killed either by very high or by very low temperature treatment or prolonged cooking. Such drastic treatment, however, affects the quality of food. Thus, processing time and temperature should be adequate to eliminate all bacterial growth. We must not over-cook the canned foods otherwise it will spoil the flavour, appearance and texture of the product.

All fruits and acid vegetables can be processed satisfactorily at a temperature of 100°C, i.e., in boiling water. The acid present in fruits and acid vegetables retards the growth of bacteria and spores. These bacteria and spores do not thrive in heavy sugar syrups, which are normally used in canning fruits. Vegetables, generally non acidic (except tomato and rhubarb), are processed at a higher temperatures of about 115 to 121°C.

Bacterial spores usually do not grow below pH 4.5 as you have read in previous chapters. We, generally process the canned products having pH less than 4.5 in boiling water but products with pH higher than 4.5 require processing at 115 to 121°C. The higher temperature can be obtained by processing in a retort under a pressure of 0.70 to 1.05 kg/cm^2 (10 to 15 lb/sq. inch). The centre of can should attain these high temperatures.

The temperature and time of processing vary with the size of the can, the larger the can, the greater is the processing time. Fruits and acid vegetables are generally processed in open type cookers, continuous non-agitating cookers and continuous agitating cookers.

The open cookers are galvanized iron tank of desired capacity. Sealed cans are placed in iron crates and immersed in the tank containing boiling water. In continuous cookers, the cans travel in boiling water in crates carried by overhead conveyors. In continuous agitated cookers, the cans are rotated by special mechanical devices to agitate the contents of the cans. Agitation reduces the processing time considerably.

The non-acid vegetables are processed under steam pressure in closed retorts. The sealed cans are placed in the retort, keeping the level of water 2.5 to 5.0 cm above the top of the cans. The cover of the cooker is then screwed down tightly and the cooker is heated by steam to the desired temperature. The period of processing (sterilization) should be counted from the time the water starts boiling or steaming. After heating for the required period, heating is stopped and the petcock or vent is opened. When the pressure comes down to zero the cover is removed and the cans are taken out.

xiv) Cooling

After processing, the cans are cooled rapidly to about 39°C to stop the cooking process. Cooling can be done by several methods such as (1) immersing the hot cans in tank containing cold water, (2) spraying cold water, (3) turning in cold water into the pressure cooker, and (4) exposing the cans to air. Generally the first method is practiced. Cooling water may be kept sterile with 1 or 2 per cent chlorine. If canned products are not cool immediately after processing, the quality is deteriorated, e.g., peaches and pears become dark in colour, tomatoes turn brownish and become bitter in taste, while peas become mashy with a cooked taste.

xv) Testing for Defects

Before the canned products are marketed, we should test them for any defect. The finished cans are tested for leak or imperfect seals. We should tap the top of the can with a short steel rod. A clear ringing sound indicates a perfect seal, while a dull and hollow sound shows a leaky or imperfect seal. Leaky cans should be removed from the lot.

xvi) Storage, labelling and packing

Before storage, the cans should be completely dry, small traces of moisture are likely to induce rusting. They should be stored in a cool and dry place. Storage of cans at high temperature should be avoided, as it shortens the shelf life of the product. The high temperature may lead to hydrogen swell and perforation during extended storage. The basement stores are useful, especially during summer months. The temperature in these stores is lower by about 6° to 8°C, compared to outside temperature. Before dispatch, the cans are labelled and packed either in wooden or cardboard boxes, and are ready for marketing. The cans may be stored for 1 to 2 years depending upon the type of raw materials used and the shelf life of the product.

3.2.3 Tin Containers

The cans are made of thin steel plate of low carbon content, lightly coated on both sides with tin metal. Sometimes discolouration of the product or corrosion of the tin plate takes place. In order to avoid corrosion, these cans are coated inside and or outside with lacquer, the process is known as "lacquering". There are two types of lacquers used.

1. Acid-resistant-Acid-resistant lacquer is a golden colour enamel, cans coated with it are called R enamel or A.R. cans. The lacquered cans are used for packing fruits having water soluble colour (anthocyanins) for example raspberry, strawberry, red plum, coloured grapes, pomegranate, etc. Fruits having water insoluble colour, for example pineapple, mango, grapefruit, etc., are packed in plain cans only.

2. Sulphur-resistant – This lacquer is also of a golden colour, cans coated with it are called C. enamel or S.R. cans. These cans are used for packing pea, corn, lima beans, etc.

The tin cans are supplied to the canning factory in flattened form, where they are reformed using a machine, reformer, into cylindrical shape. After that, they are flanged by using flanger, which curls the rings outwards at each end. The one end of the cylindrical can is then fixed, before filling it, using a machine known as double seamer. After filling, processing and exhausting the can, the lid is fixed using the same machine.

Table 3.1: Commercial can sizes and capacities

Sl. No.	Trade name of can	Size (mm)	Capacity (in cubic cm)
1.	A1	68 × 102	316
2.	1-1b Jam	78 × 90	356
3.	A1-T	78 × 119	479
4.	A2	87 × 114	579

5.	1-1b Butter	103 × 70	470
6.	A2-1b Jam	103 × 102	721
7.	A2½	103 × 119	848
8.	7-1b Jam	157 × 148	2543
9.	A10	157 × 178	3069

3.2.4 Spoilage in Canned Fruits and Vegetables

Canned products are liable to spoilage for various reasons. Spoilage in canned food may be caused due to two reasons:

A) Spoilage due to physical and chemical changes:

1. Swell – Swell or bulge in cans caused due to the positive internal pressure of gases formed by microbial or chemical action. Hydrogen Swell – This type of swelling is due to the hydrogen gas produced by the action of food acids on the metal of the can. The swelling ranges from flipper – springer, soft swell or hard swell.
2. Overfilling – Overfilling should be avoided.
3. Faulty retort operation – It gives cans look like swells.
4. Under exhausting – It causes severe strain during heat processing.
5. Panelling – It is seen in large sized cans that the body is pushed inward due to high vacuum inside.
6. Rust – Rust is mostly seen under the label and subsequently affects the label. Cans lacquered externally do not rust.
7. Leakage – Cans generally leak due to defective seaming and nail holes.
8. Bursting – Cans may burst due to excess pressure of gases produced by decomposition of the food.
9. Discolouration – This may be due to enzymatic and non – enzymatic browning. Enzymatic discolouration can be avoided by placing the peeled and cut pieces of fruits and vegetables in 2% salt solution.
10. Stack burning – The contents in the can if remain hot for a long time during storage result in stack burning. It may cause discolouration. To avoid stack burning cans should be cooled quickly to about 39^{o}C before storage.

B) Spoilage by microorganisms

The time gap between filling and heat processing may cause microbial spoilage. If cans are not processed properly they may result in spoilage by bacteria and the spoilage is termed as “Under processed” spoilage.

Various spoilages caused due to different microorganisms are:

1. Flat sour – The non-acid vegetables spoiled by Bacillus coagulens and Bacillus sterothermophilus.
2. Thermophilic acid spoilage – Cans swell due to production of carbon dioxide and hydrogen by Clostridium thermosaccharolyticum.

3. Sulphide spoilage – Caused by Clostridium nignificans in low acid foods.

So, we should process cans properly to avoid any type of spoilage.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define principles of processing.

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2. List the name of unit operations involved in the canning process.

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3. State the differences between processing of fruits and vegetables in a can.

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4. Describe the causes and types of spoilages of canned foods?

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3.3 CANNING OF FRUITS

The fruits are exhausted at 82 to 100°C for 7-10 minutes or until the centre of the can reaches at least 74°C temperature. The types of can, strength of covering sugar syrup and time-temperature for No.2½ and No.10 cans are summarised in Table 3.2.

Table 3.2: Canning time table for fruits and tomatoes

Sl. No.	Fruit	Type of can	Strength of syrup (Degree Brix)	Processing time (min) in boiling water at 100°C	
				No.2½	No. 10
1.	Apple	Plain	Water or light syrup	12	25
2.	Apricot	Plain	55	35	50
3.	Banana	Plain	30+0.2% citric acid	20	–
4.	Blackberry	Fruit lacquered	55	20	30
5.	Cherry (sweet)	Fruit lacquered	40	20	25
6.	Cherry (sour)	Fruit lacquered	45	20	25
7.	Fig	Plain	55	15	35
8.	Grape (coloured)	Fruit lacquered	40	12	15
9.	Grape (white)	Plain	40	12	15
10.	Grape fruit	Plain	60	30to 40	

11.	Guava	Plain	40	20	–
12.	Jack fruit	Plain	50	30	–
13.	Litchi	Plain	40	30	–
14.	Mango	Plain	40	30	–
15.	Mulberry (coloured)	Fruit lacquered	40	12	–
16.	Musk Melon	Plain	40+0.3% Citric acid	30	–
17.	Orange	Plain	50	15 to 20	
18.	Papaya	Plain	45	30	–
19.	Peach	Plain	55	30	50
20.	Pear	Plain	40	35	60
21.	Pineapple	Plain	40	30	60
22.	Plum, red	Fruit lacquered	40	20	30
23.	Raspberry	Fruit lacquered	45	12	25
25.	Strawberry	Fruit lacquered	50	15	20
26.	Tomato	Plain	Only tomato juice in the case of standard pack	30	70
27.	Fruit Cocktail (Fruit salad)	Plain	45	30	90

i) Apple

Apples are generally not canned. However, canned apples available in the large sizes of cans are used in pies. The varieties used for canning are: Golden Delicious, Yellow Newton, Baldwin, Jonathan, and Ambri.

The fruits should be washed in warm dilute hydrochloric acid (0.5%) solution to remove any residue of lead or arsenic sprays. And then washed thoroughly in cold water to remove traces of acid. The apples are peeled by hand or machine and cut into 0.3 to 0.6 cm thick slices. The prepared fruits should be kept in 2 to 3 per cent common salt solution to avoid darkening due to enzyme action. The prepared fruits are blanched in hot water at 71 to 81^o C for 3 to 4 minutes and then cooled in water. Blanching removes the air and gases and inactivates enzymes. The blanched fruits are filled into cans, covered with hot water or thin sugar syrup, exhausted, sealed and processed.

ii) Apricot

Apricots are mostly grown in Kashmir, Himachal Pradesh and Uttaranchal, where a great scope exists for their canning. Charmagz and Shakarkand are white sweet varieties which are good for canning. Apricots are either canned whole or halves.

iii) Banana

South Indian varieties of banana, viz. Pachabale, Chandrabale, Nendran, Poovan and Vannan are good for canning. Fully ripe bananas are selected for canning. Fruits are peeled by hand and then cut into long slices of 1 to 2 cm thickness. The slices are filled into cans and covered with a sugar syrup of 25 to 30° Brix containing 0.2 per cent citric acid. Then the cans are exhausted, sealed and processed.

iv) Ber

Umran and *Katha* varieties of *ber* are good for canning. Fully mature fruits are selected for canning. Peel is removed by hand with the help of stainless steel knife or by dipping in 5 per cent boiling hot caustic soda solution for 2 minutes and then washed in running tap water. Second washing is done in water containing 0.1 per cent citric acid in order to remove any traces of caustic soda solution. The fruits are cut into slices. The slices are filled into one lb Jam size can, exhausted; sealed, processed in boiling water for 20 minutes and cooled.

v) Berry Fruits

Among berry fruits, strawberry, loganberry, black berry, raspberry, mulberry and black and red currants are popular for canning. White heart cherry and red cherry having creamy white flesh, are good for canning. Maraschino cherries are canned for mixing with other fruits and for fruit cocktails.

The cherries for canning are generally decolourised during curing in brine for 4-6 weeks. During curing cherries are kept in a brine, which is made up of about 0.75 to 1.0 per cent sulphur dioxide (SO_2) and about 0.4 to 0.6 per cent slaked lime. The cured cherries are washed well in water and dyed with a red dye like Erythrosine, and the colour is fixed with citric acid. These cherries are used for canning.

vi) Citrus Fruits

Generally grape fruit and oranges are canned. Grape fruit varieties Marsh Seedless, Duncan and Foster are good for canning. The fruit is immersed in hot water (93 to 96°C) for 2 to 5 minutes. It softens the peel, which can easily be removed by hand. The peeled fruit is further hand peeled or lye-peeled to remove the white rag portion called albedo. For lye peeling, the whole fruit is immersed in hot lye solution containing 1.5 to 2.0 per cent caustic soda (NaOH) for 20 to 30 seconds. It is then washed with cold water and the segments are separated. The membranes and seeds are removed with the help of knife. The prepared segments are filled into plain cans, and then filled with 60° Brix syrup. The filled cans are exhausted for 25 to 30 minutes at 82 to 87°C, then sealed and processed for 30 to 40 minutes at the same temperature. The cans are cooled immediately after processing.

Satsuma, Mandarin and Unshu (in Japan) are employed for canning. Malta and Sathgudi, which are tight skin, and loose jacket Nagpur and Coorg oranges also yield good canned products.

The peel of loose jacket orange is removed by hand easily. The peel of tight skin oranges is removed and prepared similar to grape fruit. The filled cans are exhausted for 15 to 20 minutes at 82 to 87°C, sealed and pressed for another 15 to 20 minutes at the same temperature in open cooker. After processing, the cans are cooled immediately in cold water.

vii) Grape

Grape varieties such as Thompson Seedless and Muscat are good for canning. Only large sized berries are used for canning. Washed berries are filled into cans and covered with syrup of 20 to 40° Brix. The cans are exhausted, sealed and processed. The coloured grapes should be canned in lacquered cans.

viii) Guava

Fully ripe but firm fruit, with white flesh, are selected for canning. Fruits are peeled by knife or by lye solution as described above. Peeled fruits are cut into halves and seeds are scooped out with a spoon-shaped knife. The prepared fruit should be immersed in 1 to 2 per cent common salt solution. It helps to prevent the fruit from browning. Either halved or quarters are canned. The peel and core with seeds can be used for making guava jelly or guava cheese. Canned guava has a taste and aroma better than those of fresh fruits.

ix) Jack-Fruit

Jackfruit is mostly available in Maharashtra, Bihar, Orissa, Karnataka, Kerala and Tamilnadu. In these states, certain sections of the people use it as an important staple food. All parts of the fruit can be used in one or the other form of food. The green and immature fruit can be canned as a curried vegetable. The ripe fruit with the crisp bulb after seed removal is used for canning in sugar syrup.

The fruit is washed, cut into several large pieces and the bulbs are removed with hand. The fruit contains a white, highly sticky, latex so, a little vegetable oil such as til or gingelly oil, is smeared on the hand and the knife to prevent the latex from sticking on them. The latex is soluble in oil. The bulb after seed removal is canned as a whole, halved or quarter. Generally syrup of 50° Brix having 0.5 to 0.75 per cent citric acid is used for canning of jackfruit bulb.

x) Litchi

Litchis are mostly cultivated in Bihar, Orissa, Uttaranchal and Uttar Pradesh. Tree-ripened fruit is selected for canning. Fruit is washed, skin is removed, and aril is separated from stones. The aril is filled in cans, and aril covered with sugar syrup of about 40^{o} Brix containing 0.5 per cent citric acid. The filled cans are exhausted, sealed and then processed as mentioned earlier. After processing, cans are cooled promptly and thoroughly in running cold water to prevent development of pink colour in the product.

xi) Mango

In India, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Maharashtra and West Bengal lead in mango cultivation. Dashehari, Alphonso, Badami, Baneshan, Raspuri, Neelam, Mulgoa and Totapuri or Bangalora are the most important mango varieties for canning. Juicy and fibrous varieties are not suitable for canning.

Fully developed and mature fruits are harvested and ripened. Canning ripe (just ripe but firm) fruits are selected, washed with water and peeled by hand with the help of knife. The pulp is either cut into two broad side (Chick) or quartered or 6 to 8 cm longitudinal slices.

The prepared fruit is placed in two per cent common salt solution to prevent enzymatic browning. The fruit has slightly higher pH than the critical pH of 4.2 so it is necessary to add 0.3 to 0.5 per cent citric acid in the syrup in order to process in open cookers. The trimmings of the slices, pulp adhering to the peel and stone can be used profitably for the preparation of mango juice or beverages and mango jam.

xii) Papaya

Fruit is washed, peeled, seed removed and cut into slices or cubes for canning. The fruit pulp has a high pH value so it is necessary to add 0.5 per cent citric acid in the syrup to reduce the pH below 4.5. Sometimes papaya is canned with other fruits like pineapple, mango, banana, etc., to produce fruit cocktails.

xiii) Peach

There are two types of peaches, one the clingstone, where the pulp adheres to the stone tightly, and the other freestone where the pulp adheres to the stone loosely or freely. Among the clingstone peaches, Tuscan, Palora and Philips Cling are the varieties good for canning. Among the freestone peaches, Elberta, Lovell and J.H. Hale are suitable varieties for canning.

The fruits are cut into two halves and the pits removed. In large canneries, mechanically operated knives are used to cut fruit into halves and to remove the pits. The cut halves are peeled by immersing them in boiling lye solution containing 1 to 2 per cent caustic soda for ½ to 1 minute. The loosened peel is removed by washing with water. The prepared halves are filled in cans, covered with syrup, exhausted and processed in open cooker. Sometimes peach slices are also canned. Peaches are also used as an important constituent of fruit cocktail.

xiv) Pear

Pears are cultivated in Himachal Pradesh, Kashmir, Uttaranchal and hilly areas of South India. Pears are harvested fully mature, firm but green. The fruits are ripened at room temperature (23 – 26^{o} C) and soft fruits are used for canning.

The fruit is peeled with a knife and cut longitudinally into two halves. The core is removed by coring knife. The prepared fruit is placed in 1 to 2 per cent common salt solution to prevent browning. The halves are then filled into cans, covered with hot sugar syrup, exhausted, seamed and processed as usual. The cans should be cooled immediately in cold water to prevent development of pink discolouration of the fruit during storage.

xv) Pineapple

Pineapple is mostly grown in Assam, West Bengal, the West Coast of India, Andhra Pradesh and Karnataka states. Giant Kew and Queen are the two important varieties of pineapple employed for canning.

The fully mature and just ripe fruit is selected for canning. Uniform size graded fruits are peeled, cored and sliced on a Ginaca machine in foreign countries. In India, the fruits are sliced, and then core and peel is removed by hand with the help of coring and punching knife. Slices are graded usually for size. Since the fruit contains highly active proteolytic enzymes, injurious to skin, the workers should wear rubber gloves. The slices are filled into cans, covered with syrup, exhausted, seamed, processed and cooled as usual.

xvi) Plum

The Red Victoria and the Yellow Pershore plums are important canning varieties. The Alubukhara plum generally grown in North India, also gives a fairly good canned product.

Generally whole plum with stone is canned. Since plum contains water-soluble red colour, which is due to the presence of anthocyanins, is canned in lacquered cans. Washed fruits are filled into can, either as discrete number or by weight, covered with syrup and processed as usual.

xvii) Other Fruits

There are some minor and lesser-known fruits such as. Date, Pomegranate, Mulberry, Musk melon, Water Melon, Aonla, Carambola, Tamarind, Avocado, Custard Apple, Karonda, etc. which may also be canned as usual. These fruits may be canned as slices, cubes or juice and pulp or beverages.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why citric acid is added to covering syrup?

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2. State reason for placing the prepared fruits in common salt solution.

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3. Why fruits are processed in open cooker?

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3.4 CANNING OF VEGETABLES

The vegetables are exhausted at 90-100°C for 7-10 minutes or until the centre of the can reaches at least 77°C temperature. The types of can, strength of covering brine and time-temperature for No.2½ and No.10 cans are summarised in Table 3.3.

Table 3.3: Canning time table for non-acid vegetables

Sl. No.	Vegetables	Type of can	Strength of Brine (common salt)	Processing time min. at 0.7 kg per cm^2 steam pressure	
				No. 2½ Can	No. 10 Can
1.	Asparagus	Plain	2.25%	24	40
2.	Bean	Plain	2.25%	40	75
3.	Beet-root	Sulphur resistant	Water or 1.5% Brine	30	40
4.	Cabbage	Plain	2%	40	60
5.	Carrot	Plain	2%	25	50
6.	Cauliflower	Plain	2%	20	–
7.	Curried vegetables	Plain	–	60 to 70	
8.	Mushroom	Plain	2% “	25	40
9.	Okra	Plain	2% “	35	–

10.	Pea, garden	Sulphur resistant	2% Brine & 2.5% sugar solution	45	60
11.	Potato	Plain	2%	45	–
12.	Turnip	Plain	2%	35	50

i) Asparagus

he asparagus shoots are green and white. The tender shoots are used for canning. Just after harvesting the shoots are washed and graded for size and cut according to the height of the can. Shoots are blanched in boiling water for 2-3 minutes then placed in cold water. The blanched shoots are filled into sulphur-resistant cans, covered with 2.0 per cent common salt solution, exhausted, seamed and processed as usual.

ii) Beans

French beans, which are tendered and stringless are used for canning. The beans are washed thoroughly with water and cut into slices about 2.5 cm in length. The slices are blanched in boiling water, drained and filled into plain cans. The beans in the cans are covered with 2 per cent brine, exhausted, closed and processed under pressure in retorts. Sometimes diced beans with diced carrots and garden peas are also canned as mixed vegetables.

iii) Beetroot

Beetroot is washed with water thoroughly. The top and roots are removed with a stainless steel knife. The vegetable is cut in the form of discs or cubes and placed in 1 to 2 per cent common salt solution to preserve the colour. The prepared pieces are filled into vegetable lacquered cans, covered with 2 per cent brine, exhausted, seamed and processed as usual.

iv) Cabbage

Cabbage head with tender yellow leaves is used for canning. After washing, the head is cut into 4 to 8 pieces or shredded into 2.5 cm thick pieces. The pieces are generally blanched in boiling water for 5 to 7 minutes. The blanching water may preferably contain 1 per cent citric acid. After blanching it is cooled in 2 per cent brine to prevent discolouration. The prepared vegetable is filled into plain cans, covered with 2 per cent brine and processed as usual.

v) Carrot

Generally yellow varieties of carrot are used for canning. Tender and small carrots are selected for canning. The carrots are washed well and skin is scrapped with a knife. For large-scale work, mechanical peeler is employed. The peeled carrot is graded for size and used as such or cut into discs or cubes for canning. The carrot is blanched in boiling water for 8 to 12 minutes and packed into plain cans. Brine is used for canning.

vi) Cauliflower

In case of cauliflower, compact flower head is selected and cut into pieces of suitable size. The pieces are canned similar to that of cabbage.

vii) Mushroom

Edible mushrooms, which are not poisonous, are selected for canning. Button mushroom is generally canned whole. Sometimes, mushroom is bleached to a pale colour in a solution of sodium sulphite and citric acid. They are washed with water and blanched in boiling water for 4 to 5 minutes and subsequently dipped in cold water to prevent discolouration. Blanched mushrooms are filled into plain cans, covered with 2 per cent hot brine, exhausted, seamed, processed as usual.

viii) Okra

Okra is also known as Lady's finger. Tender green okras of uniform size are selected. Okra is canned as a whole or as slices. These are washed and blanched in boiling water for 1 to 2 minute and then cooled in brine containing 1.5 per cent common salt. This helps in removal of mucilage. The blanched okras are filled into plain cans and covered with 2 per cent brine, exhausted, seamed and processed as usual. Sometimes, the okras are also canned with thick tomato sauce in order to overcome the mucilaginous property.

ix) Peas

Bonneville is the most popular pea variety for canning in India. We should see that the peas for canning are uniformly ripe and should retain the green colour even after processing. They should also possess good texture and flavour. Large size peas are generally preferred for canning.

Peas are shelled by pea-podding machine and graded by size using sieves with mesh ranging from 0.7 to 1.0 cm. The graded peas are blanched in boiling water for 2 to 5 minutes, and rinsed in cold water. They are filled into plain cans by hand or machine and covered with 2 per cent brine. Sometimes, 2 per cent cane sugar is also added in brine to improve the flavour of the peas. An edible and FPO permitted green colour also may be added to the brine. The cans are exhaussted, closed and processed in a retort as usual. Canned fresh peas are generally known as 'green peas' or 'garden peas'. Dried peas are also canned. The dried peas, which are soaked in water, are canned similar to fresh peas. The dried canned peas are known as 'processed' peas.

x) Potato

Potatoes are canned either whole or slices. Good starchy and firm potatoes are selected and washed to remove the adhered soil. Potatoes are peeled with a knife or by potato peeler, a machine having abrasive surface to remove peel. Peeled potatoes are kept in 2 per cent common salt solution to prevent discolouration. Peeled potatoes are blanched in boiling water for 5 to 7 minutes. Blanched pieces are filled into plain cans, covered with 2 per cent brine, exhausted, seamed, processed and cooled as usual. Some varieties of potato turn bitter after canning, which should not be used.

xi) Tomato

Tomatoes for canning should be firm ripe, medium in size, regular in shape, and of uniform red colour. Tomatoes should have plenty of pulp and free from blemishes.

Tomatoes after washing are placed in boiling water or steam for 2 to 3 minutes to crack the skin and then washed in cold water to remove peel easily. Any green patch is trimmed out. The peeled and trimmed tomatoes are filled into plain cans and covered with tomato juice; and after exhausting and seaming processed in open cooker. It's processing is different from other vegetables as it is acid food.

xii) Turnip

Turnips are red, white and yellow in colour but generally white turnips are canned. Select fibre free tender turnips. They are washed thoroughly with water and cut into about 1 cm thick slices. The pieces are blanched in boiling water for 3 to 5 minutes and cooled. The blanched turnips are filled into cans, covered with 2 per cent brine and processed in retort as usual.

xiii) Other Vegetables

There are several other vegetables, which may be canned similar to the methods given above. They are Karela, Tinda and Parwal. Spinach (Palak) is also canned as puree.

Sarson-ka-Saag (Mustard Green)

Sarson-ka-saag is generally prepared from mustard leaves and spinach in the ratio of 4:1. It has good demand as canned product in India and abroad. The tender shoots of green mustard and spinach are washed, chopped and cooked with salt for 40-45 min. Then mashing is done along with the addition of corn flour or Bengal gram flour (besan). The mass, then fried along with other ingredients and filled into cans, exhausted for 10 minutes and sealed. The cans are processed for 50 minutes in a retort at 0.7 kg/cm^2 and cooled to room temperature. A general recipe for canning of sarson-ka-saag is given below:

Mustard green chopped	800g
Spinach chopped	200g
Tomato	100g
Onion	100g
Garlic	20g
Ginger	80g
Ghee/Oil	100g
Salt (to taste)	15g
Chilli	10g
Corn flour or besan	50g

xiv) Curried Vegetables

Canning of vegetables in brine is a western way of preserving and consuming. There are certain vegetables that are canned as we cook them along with spices and condiments. Certain vegetables like potato, cauliflower, peas, tomatoes are cooked in combination or alone and canned as curried vegetables. Curried vegetables are those vegetables, which are canned along with spices and condiments such as mustard, coriander, red chilli, turmeric, common salt and vegetable oil in form of gravy. The curried vegetables are readily consumed after heating in the cans. In order to prepare the curried vegetables, the oil is heated in a pan, the mustard seed is fried in it, then other ingredients in powder form are added to taste (as done at home while cooking vegetables) and heatings continued. Then required amount of water is added and brought to boil. The curried vegetables are filled into can along with gravy, closed and processed for 60 to 70 minutes at 0.7 kg/cm^2 in a retort.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why non-acidic vegetables are processed at high temperature in a retort?

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2. Why certain vegetables are not packed in plain cans. Give names and reasons?

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3.5 ASEPTIC CANNING OF FRUIT AND VEGETABLE PRODUCTS

Fruit and vegetable products are packed by using the latest developed technique known as aseptic canning. As you know that this system is basically a high temperature short time (HTST) sterilizing process. This method combines flash sterilization and cooling with aseptic methods of packaging for fluid and semi-fluid products, thus eliminating retorting and cooling. It is being used commercially particularly for bulk packing of products. This system has advantage that quality of the product is maintained better. The nutrient losses are minimum due to HTST processing and shelf life of the product is more.

3.6 LET US SUM UP

Canning is a method of preservation of fruits and vegetables by heat application. The main principle of canning is the destruction of spoilage microorganisms. The canning process includes several unit operations, viz. selection, sorting, grading, washing, peeling, cutting, blanching, filling, syruping or brining, lidding or clinching, exhausting, seaming, processing, cooling and storage. Fruits and vegetables differ in the canning process due to their acid value.

Tin cans of different sizes are used for packing of fruits and vegetables. For some fruits and vegetables lacquer cans are used. If cans are not processed adequately they develop some defects. The defects may be caused by physical and chemical changes, and by microorganisms. Canned products can be stored for 1 to 2 years depending on the quality of raw materials.

3.7 KEY WORDS

Blanching : Blanching is done by immersing fruits and vegetables in hot water or by exposing to steam followed by cooling.

Syruping or brining : After placing prepared fruits or vegetables in can, syrup or brine is added, respectively is called syruping or brining.

Exhausting : The vacuum in the can obtained by heat treatment or by mechanical means is known as exhausting.

Seaming : It is sealing or closing of lids on cans by double seamer. Interlocking of curl of the lid and flange of the can creates double seam.

Processing : The application of heat to fruits and vegetables after hermetic (air tight) sealing in containers is called processing.

Commercial sterilization : It is the term used for those thermally processed products in which microorganisms and their spores do not grow under normal conditions of storage.

Principle purpose of canning : Destruction of spoilage or pathogenic microorganisms and retention the original characteristics of food.

Unit operation : It is one of the steps in a complete process or a physical change in form or place, for example, peeling, cutting, grading, etc.

3.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. • Destruction of microorganisms, which may cause spoilage of foods.
   • Improve the flavour, texture and appearance of food by cooking.
   • Prevent recontamination.

2. Selection of fruits and vegetables → Sorting and Grading → Washing → Peeling → Cutting → Blanching→ Filling → Syruping → Lidding/Brining or Clinching → Exhausting → Seaming → Processing → Cooling → Testing for defects → Storage

3. • Fruits are covered with sugar syrup while vegetables are covered with brine
   • Fruits are processed at 100°C while vegetables are processed at 115° to 121°C.
   • Fruits are processed in open cookers while vegetables are processed in retort under pressure(0.7kg/cm^2)

4. i) Spoilage due to physical and chemical changes:
      • Swell – Hydrogen swell; Flipper, Springer, etc.
      • Overfilling, faulty retort operation, under exhausting, panelling, rust, leakage, bursting, discolouration and stack burning

   ii) Spoilage by microorganisms
      • Flat sour.
      • Thermophilic acid sour
      • Sulphur spoilage, etc.

Check Your Progress Exercise 2

1. Your answer should include the following points:
   • To lower the pH of canned fruit
   • To improve the palatability of canned product

2. Your answer should include the following points:
   • To prevent enzymatic browning
   • To prevent darkening
   • To prevent discolouration

3. Your answer should include the following points:

- In open cooker, normal atmosphere is maintained
- In open cooker temperature of boiling water remain & below 100°C and never increases.
- The fruits and tomato (acidic vegetables) are cooked generally in the open cooker.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Vegetables are generally non acidic in nature
   - The pH of non acidic vegetables are above 4.5
   - Non-acidic vegetables are processed at high temperature
   - High temperature can only be attained when processed under pressure in a retort.

2. Your answer should include the following points:

   - Certain vegetables contain water soluble colour
   - Presence of anthocyanins
   - Presence of sulphur compound
   - Asparagus, Beetroot, Peas are packed in lacquered cans

3.9 SOME USEFUL BOOKS

1. Cruess, W.V. (1997) Commercial Fruit and Vegetable Products, Allied Scientific Publishers.

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4. Ranganna, S. (2000) Hand Book of Canning and Aseptic Packaging, Tata McGraw-Hill Publishing Company Limited, New Delhi.

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UNIT 4 FORMS OF WATER IN FOODS, SORPTION AND DESORPTION OF WATER IN FOODS AND WATER ACTIVITY

Structure

4.0 OBJECTIVES

After reading this unit, you should be able to:

- state the meaning of water activity and water sorption isotherms;
- explain the properties of water in solutions;
- describe the effect of water activity on various biochemical reactions, microbial growth, food preservation, etc.; and
- discuss the water activity in packaged and stored food.

4.1 INTRODUCTION

All foods provided by nature, contain water. High water content in foods is most likely to show rapid deterioration due to biological and chemical changes. Our ancestors found that spoilage could be delayed or prevented by drying perishable foods. The water in foods serves as a solvent for many constituents. The removal of water will concentrate these constituents. The increasing concentration, rather than decreasing water content, preserves the food. Water can be removed by heat, sun's radiation, salt or sugar. Thus, any method increasing the concentration of a food's aqueous phase enhances its stability.

Therefore, study of water in foods is also a study of aqueous solution in which the solutes, by their nature and concentration, alter the physical properties of the solvent. It is the state of water in food which influences the microbial growth, enzymatic and non-enzymatic reactions. By controlling the water content, or concentrating the food solution, we may stabilize the food for a longer period. The water content influences the biological or chemical changes, and these changes affect the taste, texture and appearance of the food.

Thus, there is a water related criteria, viz. water content, solute concentration, osmotic pressure, equilibrium relative humidity (E.R.H.), and water activity (a_w). It is the water activity, which is the most useful expression of water requirements for microbial growth and enzyme activity. It becomes more important in defining the quality of food material. Thus, by controlling the water activity of fruits and vegetables, we may predict the freshness, or storability of their processed products.

4.2 PROPERTIES OF WATER IN SOLUTIONS

Water has its own property. When solutes are dissolved in water, the water molecules become oriented with respect to solute molecules. In simple word water molecules and solute molecules are engaged with each other. The water molecules become less free to escape from the liquid into the vapour phase, and the vapour pressure is lowered. There is a relationship between solutes concentration and vapour pressure of liquid or solution. It indicates that with increase in solute concentration, vapour pressure decreases, and it lowers the freezing point but it raises the boiling point of the solution.

The water activity is described as the ratio of water vapour pressure of food (solution) to the water vapour pressure of pure water (solvent) at the same temperature and expressed by

$$a_w = P/P_o$$

P = Vapour pressure of food
P_o = Vapour pressures of pure water

It is expressed as a fraction but under equilibrium condition, equilibrium relative humidity (E.R.H.) is equal to $a_w \times 100$, provided that its vapour pressure is not reduced. The pure water has the water activity of 1.00, which is equivalent to an E.R.H. of 100 per cent. Thus, a food with a water activity of 0.8 would produce an E.R.H. of 80 per cent.

Any addition of solutes in water influences the water activity. For example, an ideal solute of 1 molal concentration has a_w 0.9823, but glycerol has 0.9816, sucrose has 0.9806, while has sodium chloride 0.967. The difference in water activity may be small for non-electrolytes but for electrolytes the difference in water activity is always great. It increases with the increase in the number of ions generated per molecule.

4.3 WATER SORPTION ISOTHERMS

A percentage of total water in a food is strongly bound to specific sites, e.g. hydroxyl groups of polysaccharides. When all sites are (statistically) occupied by adsorbed water the moisture content is termed monolayer value. This monolayer value represents the moisture content at which the food is most stable.

It influences certain chemical reactions. For example, lipid oxidation rates increase at water contents below the monolayer, while rates of non-enzymatic browning increase above it. The capillary forces in foods also influence the water activity, generally it depresses water activity.

To understand the water relations of a food, the water activity levels corresponding to a range of water content must be determined. The data are plotted to provide a water sorption isotherm (Figure 4.1).

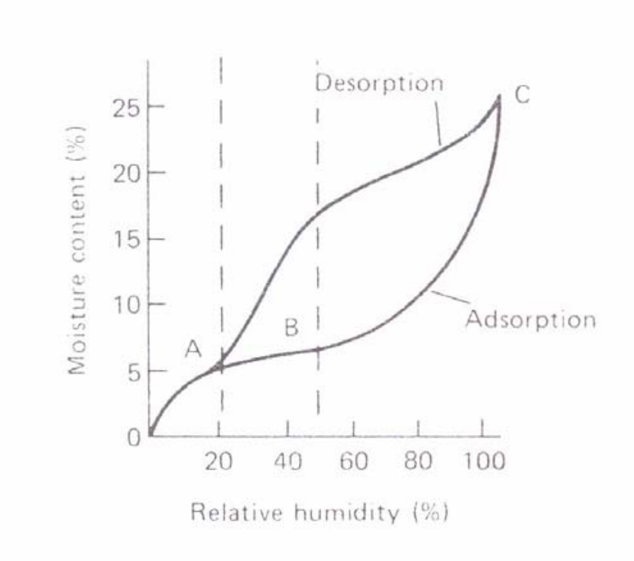

Figure 4.1: Water sorption isotherms

The graphical relationships between water content and water activity (a_w) are termed "isotherms" and the loop is fermed as hystoresis loop. Any changes in temperature affect this relation. Thus, water taken by a dry food is termed adsorption and water removed from a moist material is termed desorption. The difference is greatest at lower temperature (5°C) and not detectable at higher temperature (60°C).

There are different stages of water sorption. In theory, the course of water sorption by a dry material is first by the formation of a monolayer, followed by multiplayer adsorption, the uptake into pores and capillary spaces, dissolution of solutes, and entrapment of water at higher levels of water activity. These phases or stages vary in the food product depending upon chemical composition and structure. Thus, we find that water activity plays a great role in the study of freezing and dehydration of fruits and vegetables. By controlling water activity of the food, oxidative changes and microbial growth can be checked. The water activity can be a basis for the standard specification of food material. And it also becomes the basis of guidelines, for pickled, fermented and acidified foods.

4.4 WATER ACTIVITY AND METHODS

The water in food, which is not bound to its molecules, can support the growth of microorganisms. This unbound or free water is also termed as water activity (a_w).

The water activity and moisture content of a food are not the same. The various foods may have exactly the same moisture content but have different water activities. For example, jams, jellies and plum puddings have 0.8 $a_{w,}$ while dried fruits have 0.6 a_w.

The water activity can determine the shelf life of a food. There are several factors, including the temperature and pH, that influence the growth of the organisms in food, but water activity may be the most important factor in controlling spoilage. The water activity can predict which microorganisms will and will not be potential cause of spoilage. Hence, the water activity plays a role in determining the activity of bacteria or enzyme, which can have a major impact on the colour, taste and aroma of the product. There are several food preservation methods which to eliminate spoilage by reducing the availability of free water to microorganisms. The processes such as concentration, dehydration, freeze-drying and freezing can reduce the amount of free water in a product.

Water activity or equilibrium relative humidity of a food effects its quality during processing storage, transportation, marketing etc. Any change in the water activity of specific food may lead to the changes in its quality.

Moisture measurement techniques have been classified into three groups based on function: (i) water activity, (ii) atmospheric relative humidity, and (iii) total moisture. The first group deals with direct water activity / E.R.H. measurements as related to foods. The second group deals with relative humidity measurements, which covers food related activities, for example, ambient relative humidity in food storage areas. The third group deals with measurement of total moisture content, regardless of the condition or degree of water binding. These measurement methods are listed below.

Graphic Interpolation, Bithermal Equilibrium, Manometer, Hair Hygrometry, Isopiestic Equilibration, Electric Hygrometry, Chemical Methods, Freezing Point Depression, Dew Point Methods, Relative Humidity Methods, Thermometric Methods, Total Moisture Methods, Gravimetric, Gas Chromatography, Karl Fischer Titration, Nuclear Magnetic Resonance, Thermal Analysis, Moisture Evolution Analysis, Infrared, Vacuum Oven Drying, Solvent Extraction.

The control of water activity in processed products of fruits and vegetables is essential for maintenance of their wholesomeness, safety, texture, and for suppression of undesirable enzymatic and chemical changes. These objectives can be achieved by utilizing water activity adjustment as a legitimate means of food preservation. The water activity adjustment in a food is also affected by a large number of substances added to the food.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe water activity.

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2. What do you understand by water sorption isotherms?

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3. List some methods which can measures the water activity.

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4. Why measurement of water activity is essential?

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4.5 EFFECT OF WATER ACTIVITY ON ENZYME REACTIONS

Enzymes are proteinaceous substances that catalyze organic reactions. The enzymatic reactions may be beneficial or detrimental changes occurring in foods. For example, the addition of a proteolytic enzyme, which acts as chill proofing agent, to beer to prevent precipitation of proteins when it is refrigerated. These enzymes develop in foods through the growth of specific types of microorganisms. For example, proteases and lipases synthesize by the mould, *Penicillium roqueforti* that produces desirable flavours during ripening of blue cheese.

Certain enzymes catalyze detrimental changes in food, such as non-microbial decomposition of fruits and vegetables during handling and storage. The enzymes, viz. peroxidase may cause browning; ascorbic acid oxidase may cause oxidation of ascorbic acid. It is therefore, important to thwart the activities of these naturally occurring enzymes in foods. Blanching of fruits and vegetables by hot water or steam is one method to inactivate enzymes and prevent the deleterious changes.

The enzymes also produce free radical by hydrolytic reactions. The water participates actively in these reactions. These reactions are not limited with low moisture foods, since many enzymatic reactions cease at higher concentration than that required for hydrolysis. At low water activity levels free mobile water monolayer is not available to carry out reactions. Under such conditions the enzymatic reactions are suppressed. But, when the water activity of food increased, the enzymatic reaction rates increase. Thus, by controlling water activity, we can check the enzymatic reaction rates. In other words, we may increase the rates of beneficial reactions and reduce the rates of deleterious reactions, and maintain the desired quality of foods.

There are certain enzyme preparations, which can be used to affect desirable changes in foods, These enzyme preparations can be stabilized by use of certain substances such as sodium chloride, glycerol, or propylene glycol. There are other factors, which also affect the stability of enzymes in foods, such as temperature, pH, ionic strength, moisture level, nature of food, time of storage, presence of activators and inhibitors, etc.

The enzymatic activity virtually ceases at water activity values below monolayer value. This is due to the low substrate mobility and its inability to diffuse to the reactive site on the anzymes.

Fungal proteolytic enzymes are strongly inhibited by 2-3% sodium chloride (NaCl), as the activity is in the range of 0.6-0.8. The optimal water activity levels for invertase activity is greater than 0.997. In a glycerol / water mixture, lipoxidase and peroxidase exhibit optimal activity in the range of 0.94-0.97 water activity.

4.6 EFFECT OF WATER ACTIVITY ON NON-ENZYMATIC BROWNING REACTIONS

The water activity plays a great role in influencing the non-enzymatic browning (NEB) reactions in the processed fruit and vegetable products. The substrates for NEB are the reducing sugars such as glucose and fructose and amino groups of amino acids or proteins. Sucrose may be a substrate but does not cause browning. Hydrolysis of sucrose into glucose and fructose during processing may cause browning. A number of factors such as temperature, pH, and water activity also affect the NEB reactions. They are called the formation of browning or Maillard reaction products. These browning reactions deteriorate the quality of the processed products.

The water activity that causes the maximum rate of browning varies with different foods. At low water activity browning is reduced due to lower mobility of reactants, whereas at higher a_w browning is maximum. During browning, condensation reaction produce water and at higher moisture levels, browning is inhibited by end product inhibition. At higher moisture contents, water dilutes the reactants and the rate of browning falls.

Browning that occurs during processing or storage may either increase or decrease the acceptability of a food. For example, in a dehydrated pea soup stored at 54°C, a steady increase in browning rate occurs as the relative humidity of the system is increased. The maximal rate occurs in the 65-70%

relative humidity range. Thus, the temperature and moisture content during storage influence the browning rate in dehydrated products. NEB is a serious problem in the production of intermediate moisture food (IMF), since they are poised at 0.6-0.8 water activity, which places them well within water activity ranges for optimal browning. If the water activity is reduced to the range of 0.40 to 0.50 from 0.65 to 0.75 the browning of IMF can be reduced.

It is clear from the above discussion that maximal browning reaction rates in fruit and vegetable products occur in the 0.65-0.75 water activity range. By checking the water activity we can reduce the non-enzymatic browning.

4.7 EFFECT OF WATER ACTIVITY ON MICROBIAL GROWTH AND SURVIVAL

4.7.1 Microbial Growth

Food is spoiled by microorganisms, i.e. bacteria, yeast and moulds. There are four main phases of the growth cycle of these microorganisms, viz. the lag phase, the logarithmic phase, the stationary phase, and the death phase. Bacteria, yeasts and fungi reproduce by different methods such as binary fission, budding or by hyphal extension, respectively. But the phases through which these organisms pass are broadly similar.

The first phase, i.e., the lag phase, is the period of adjustment or adaptation. Physiologically the microorganisms are very active during this phase. The organisms are metabolizing, but there is a lag in cell division. At the end of the lag phase, each organism divides. However, since all the organisms do not complete the lag period simultaneously, there is a gradual increase in the population until the end of this period, when all cells are capable of dividing at regular intervals. The lag phase is followed by rapid growth, i.e., the exponential or logarithmic phase. During this period, the population is nearly most uniform in terms of chemical composition of cells, metabolic activity, and other physiological characteristics.

The logarithmic phase of growth is followed by a levelling off, the stationary phase. During this phase, the population remains constant for a time, perhaps because the reproduction rate is balanced by an equivalent death rate. Following the stationary phase, the organisms may die faster than new ones are produced, if indeed some organisms are still reproducing. During the death phase, the number of viable organisms decreases exponentially, essentially the inverse of growth during the lag phase.

We should understand that the important criterion in the water relations of a particular microorganism is the minimal water activity permitting growth. From the point of view of food technology and preservation of fruit and vegetable products, less extreme effects may also be detrimental. For example, at certain water activity levels, the population of a microorganism may be insufficient to produce a toxic product or an infectious dose. The reduced water activity along with another chemical or physical agent such as pH or common salt may have synergistic inhibitory effect on the growth of any microorganism. Thus, it is important to consider the effects of water activity on microbial growth and survival.

In general, the microorganisms associated with foods, moulds are more tolerant of a decreased a_w than yeasts, and yeasts are more tolerant than bacteria. In high moisture foods ($a_w > 0.90$) bacteria are mainly responsible for spoilage, food poisoning or fermentation. In intermediate moisture foods (a_w 0.90-0.60) yeasts and moulds are of significance in spoilage. However, most microorganisms re inhibited in low moisture foods ($a_w < 0.60$).

The a_w of most fresh foods is above 0.99. Most spoilage bacteria do not grow below a_w of 0.91 while spoilage moulds can grow as low as 0.80. With respect to food poisoning bacteria, *staphylococcus aureus* has been found to grow at as low as 0.86, while *clostridium botulinum* does not grow below 0.95 a_w. Just as yeasts and moulds grow over a wider pH range than bacteria, the same is true for a_w. The lowest reported values for bacteria of any type is 0.75 for halophilic bacteria, while xerophilic moulds and osmophilic yeasts have been reported to grow at a_w values of 0.65 and 0.60, respectively.

Inhibition of microorganisms in a food is frequently not caused solely by a decrease in a_w, but may also be influenced by pH, temperature, nutrition, preservatives or a competitive microflora. At any temperature, the ability of microorganisms to grow is reduced as the a_w is lowered. The range of a_w over which growth occurs is greatest at the optimum temperature for growth. The presence of nutrients increases the range of a_w over which the organisms can survive.

Factors affecting the germination of spores *clostridium batulinum* have indicated interaction or combined effects of a_w, temperature, pH, oxidation – reduction (O-R) potential, and sodium chloride and sodium nitrate concentrations. Addition of solutes such as glycerol and common salt also influences the water activity of a solution. This shows the availability of solvent or water in a solution, since it reduces with the addition of solutes. Such conditions also influence the growth of microorganisms. For example, non-osmophilic yeast, *saccharomyces*, grows at water activity levels down to 0.93-0.92 in sodium chloride and to 0.91-0.90 in sucrose media. But the osmophihlic yeast will grow in more concentrated environment, i.e., sugar rich and salt-rich foods.

Thus, depending upon the type of microorganism, water activity along with solutes and other factors can be selected to enhance or restrict their growth.

4.7.2 Microbial Survival

The survival of microflora is of concern during two stages of fruits and vegetables. Firstly for short period during processing and secondly for long periods during storage. We should adopt measures to prevent the growth of these microflora. We are concerned especially with the survival of microorganisms in commercially processed fruit and vegetable products. These may be frozen, dried or canned products.

Similar to the rate of multiplication, the rate of inactivation of microorganisms tends to be exponential. It shows that the same proportion of the viable population will be inactivated in each succeeding unit of time. If we plot, the number of viable cells against time, a linear curve would be obtained, and from it rate of death can be determined. This is generally expressed as the decimal reduction time or D-value. It is the time required to destroy 90 percent of the organisms. Mathematically, it is equal to the reciprocal of the slope of the survivor curve and is a measure of the death rate of an organism.

Storage stability of frozen and dried foods

A large number of microorganisms have been reported to grow at and below 0°C. Their growth at and below freezing temperatures depends on several factors of foods, namely, nutrient content, pH, and the availability of liquid water. The a_w of foods may be expected to decrease as temperatures fall below the freezing point. In fruit juice concentrates which contain comparatively high levels of sugars, these compounds tend to maintain a_w at levels higher than would be expected in pure water, thereby making microbial growth possible ever at subfreezing temperatures. Bacteria differ in their capacity to survive during freezing, with the cocci being generally more resistant than gram negative rods. Of the food poisoning bacteria, salmonellae are less resistant than *staphylococcus aureus* or vegetative cells of *clostridia*, while endospores and food poisoning toxins are apparently unaffected by low temperatures.

The heat resistance of microbial cells increases with decreasing humidity or moisture. The preservation of foods by drying is based on the fact that microorganisms and enzymes need water in order to be active. Although some microorganisms are destroyed in the process of drying, this process is not lethal to microorganisms, and indeed many types may be recovered from dried foods. Osmophilic yeasts such as *Saccharomyces rouxii* strains have been reported to grow at an a_w of 0.65 under certain conditions. The most troublesome group of microorganisms in dried foods are the moulds, with the *Aspergillus glaucus* group being the most notorious at low a_w values. In the absence of fungal growth, dessicated foods are subjected to certain chemical changes which may result in the food becoming undesirable upon holding.

Drying usually is accomplished by the removal of water, but any method that reduces the amount of available moisture, i.e., lowers the a_w, in a food is a form of drying. Thus, for example, dried fish may be heavily salted so that moisture is drawn from the flesh and bound by the solute and hence is unavailable to microorganisms. Sugar may be added, as in sweetened condensed milk, to reduce the amount of available moisture.

The potentials of reduced water activity in food preservation with the following considerations are:

i) an a_w of 0.85 inhibits the most common food pathogens,

ii) bacterial spore germination is inhibited at relatively high a_w values,

iii) non-sporeformers, which can grow at an aw below 0.95, are susceptible to pasteurizing temperatures,

iv) sub-optimal conditions of growth impose inhibition at higher levels of water activity,

v) organisms that will grow at low water activities multiply very slowly, and

vi) yeasts and moulds can be suppressed by antimycotics.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How does water activity affect enzymatic reactions?

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2. Explain "controlling water activity can reduce non-enzymatic browning."

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3. Describe the effects of water activity on the microbial growth.

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4.8 EFFECT OF WATER ACTIVITY ON PACKAGING AND STORAGE

The conditions during storage and transport should be maintained in such a way so that any deterioration is kept to a minimum. These problems are influenced by the temperature and relative humidity during storage and by the type of package in which foods are stored. Therefore, we should consider the water activity requirement in the packaging, storage and transportation of food products.

i) Transportation of processed products

During transportation of processed products the moisture migration may cause condensation. This has proved to be a problem in successful transportation of some commodities due to differences in climatic zones. For example, if cooling is followed by an increase in atmospheric temperature then humidity causes condensation on the inner surface of any container. This causes an increase in the relative humidity of the air above 90 per cent, but aeration can reduce it to a safe level.

Similarly, condensation of moisture on the surface of containers such as canned foods may spoil the label, corrode the can and mould attack. This type of problem can be prevented by drying the container before loading and lacquering the can from outside.

In the atmosphere of equilibrium relative humidity (ERH) a commodity at low water activity, even small decrease in air temperature may cause moisture condensation. For example, the air at 70 per cent ERH and 30^{o}C becomes saturated and hence prone to moisture condensation if its temperature falls by only 6^{o}C, such conditions may also permit the mould growth.

ii) Packaged products

Packaging generally reduces the atmosphere of a commodity to a minimum, hence protects it from outside sources, particularly the migration of moisture and variation in temperature. The quality of a food depends upon its properties, packaging material and the storage environment. We are concerned with the changes influenced by water activity, particularly appearance, taste, odour and texture, resulting from microbiological and biochemical changes. Packages are expected to provide adequate degree of protection to the product. With advances in packaging technology, packages are often expected to provide nutritional and constitutional information to sell the product. The packaging material has to provide desired water activity, which is the main concern. But, there are special requirements that include protection from light and oxygen, retention of preservatives, fragility of the product and the ease with which the package can be filled, handled and stored. Properly sealed cans and glass bottles give complete protection to the packed food against the intake of gases, moisture and microorganisms. The more attention should be given to the flexible films or packaging materials, which exhibit a very wide range of moisture (vapour) and gas permeability.

iii) Packaging materials

The basic flexible materials of importance are aluminium, plastic, regenerated cellulose and paper. The overall permeability of aluminium foil and laminate is near zero. The permeability of plastic film is governed by its thickness. Thicker films generally have lower permeability, greater strength and higher cost. In food packaging application, the materials are combined by lamination, coating or co-extrusion, and they may have properties different from the basic or individual film. Type of food product, its hygroscopicity, environment inside and outside of package, handling during storage, marketing, transportation, etc., usually govern this type of combination of packaging materials. Sometimes, microbiological problems may arise. When moist product is packed in impermeable or low permeable materials, such as glass, metal or films coated with polyvinylidene chloride or polyvinyl chloride, the food will equilibrate with the internal atmosphere of the package, and cooling may cause condensation of moisture, resulting in high water activity in which microbial growth may occur. Hence, we should see that product of relatively low water activity be packed in moisture impermeable packages and some measure of microbial control should also be used. Although, when high water activity products are packed in permeable material, then care must be taken to prevent excessive moisture loss from the product. This can be achieved by careful selection of wrapping material or by control of humidity in the surrounding atmosphere of the package.

iv) Unrefrigerated packaged products

Dehydrated vegetables, which have water activity of 0.30 or below, require protection against moisture and oxygen. Laminates of polyethylene, aluminium foil and paper have been successfully employed for packaging dehydrated vegetables. Dehydrated soups are also packaged similar to dried vegetables, which provide full protection to the product. The dried fruits have much higher water activity levels, may be stored safely in relatively permeable film, where ambient humidity is very low. The potato chips and roasted nuts which depend on their appeal and crispness are not susceptible to unsuitable storage conditions. These products have substantial amount of lipids, hence need additional protection, and therefore hence packaged with nitrogen gas. But for long storage costly items like nuts vacuum packaging in cans or glass jars require. However, for retail marketing, these products are successfully packaged in a wide variety of materials with low water vapour transmission rate, and oxygen permeability. For example, cellulose-plastic combination, poly vinylidene chloride coated-cellulose or polypropylene are used.

v) Refrigerated packaged products

Generally, fresh fruits and vegetables are kept in cool store at suitable temperatures and relative humidity (RH). For example, cured onions and garlic can be stored at 0°C with RH 65-70 per cent, whereas vegetables like cabbage, carrots, cauliflower, leafy greens, green peas, turnip require 95 per cent of RH. Apples are stored at 0-3°C with 85-90 per cent RH depending upon non-chilling and chilling sensitive varieties.

A compromise is required between packaging material of fresh fruits and vegetables that retain water and maintain crispness, but cause condensation and fogging of the films and those which permit loss in weight and crispness, but do not fog. Sometimes, adequate perforations are made in the package for minimum respiration without physiological disorders in the living tissues. Frozen vegetables are commonly packed in polyethylene or paperboard, waxed or plastic coated moisture proof film, to minimize oxygen uptake and loss of moisture. The frozen fruit juice concentrates are packaged in hermetically sealed tin cans or aluminium laminated composite containers.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe the role of water activity in packaged products during storage?

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4.9 LET US SUM UP

The fruits and vegetables by nature contain high water; consequently they are highly perishable products. Most likely they show rapid deterioration due to biological and chemical changes. Water acts as a solvent in the food products. The solutes present in aqueous phase, by their nature and concentration, alter the properties of solvent. It is the state of water in food products, which influences the microbial, enzymatic and non-enzymatic reactions. Thus, controlling the water content or concentrating the food solution, the food may be stabilized for a longer period. The solution of food (fruits and vegetables) has its properties, and may be expressed as water activity. The water activity is certainly related with properties of food and has great importance to study its influence on microbial growth/ survival, moisture content of food, packaged food during storage, transport and preservation.

Many enzymatic reactions cease at higher water content than that is required for hydrolysis. At low water activity levels, the free moisture is not available, hence enzymatic reactions are suppressed. The maximum non-enzymatic reactions occur in food equilibrated to 0.65-0.70 water activity, but reduce at higher and lower water activity levels.

The lower level of water activity suppresses microbial growth in food products. Removal of water from foods, reduces its water activity, hence preservation is affected.

Properly prepared fruit and vegetable products, packed in appropriate packaging material and stored under controlled conditions have longer shelf life.

4.10 KEY WORDS

Water activity : Water activity (a_w) is the ratio of vapour pressure of food (p) and pure water (p_o), and expressed by $a_w = p/ p_o$

Sorption isotherm : Water sorption isotherm is a graphical presentation of data which shows the water relationship of a food.

Concentration	:	It is the removal of water from foods mostly by heat application and concentration of soluble solids or solutes.
Enzyme	:	Enzyme may be defined as proteinaceous compounds that catalyse organic reactions.
Preservation	:	Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutritious and free from any microbial infection.
Halophilic bacteria	:	They are salt tolerant bacteria. The extremely halophilic bacteria have evolved to grow only at low levels of water activity and only when these levels are produced by high sodium chloride concentrations.
Osmophilic yeast	:	Sugar tolerant yeast.
Adsorption	:	The taking up of one substance at the surface of another.
Desorption	:	Removal of adsorbed water from a solid. Reverse process of adsorption.
Adsorption isotherm	:	The relation between the amount of a substance adsorbed and its pressure or concentration at constant temperature.
Xerophilic	:	Microorganisms able to inhabit places where the water supply is scanty, or where conditions, e.g., excess of salt, make it difficult to take in water.

4.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercises 1

Your answers should include the following points:

1. The water activity is described as the ratio of vapour pressure of solution (food) and vapour pressure of solvent (water) and expressed by

$$a_w = p/\,p_o$$

a_w = Water Activity

p = Vapour pressure of solution (food)
p_o = Vapour pressure of solvent (water)

Under equilibrium condition, E.R.H. is equal to $a_w \times 100$. Provided that its vapour pressure is not reduced. The pure water has an a_w of 1.00, which is equivalent to an E.R.H. of 100 per cent.

2. To understand the water relations of a food, the water activity levels corresponding to a range of water contents must be determined. The data are plotted to provide a water sorption isotherm. The water sorption isotherm is a graphical presentation of data, which shows the water relationships of a food. It is useful in showing at what water contents certain desirable or undesirable levels of water activity are achieved.

3. The following methods can be used to measure the water activity:

   Graphical Inter Polation, Bithermal Equilibration Mamometry, Hair Hygrometry, Isopiestic Equilibration, Electric Hygrometry, Chemical methods, Freezing Point Depression and Dew Point Method.

4. The measurement of water activity in a food is essential for maintenance of their wholesomeness, safety, texture, and for suppression of undesirable enzymatic, and chemical changes.

Check Your Progress Exercises 2

Your answers should include the following points:

1. Enzymes are proteinaceous substances that catalyze organic reactions, which may be beneficial or detrimental, occurring in foods. The water participates actively in these reactions. Many enzymatic reactions cease at higher water content than that required for hydrolysis. At low water activity levels, the free mobile water is not available to carry out reactions. Under such conditions the enzymatic reactions are suppressed, but when water activity of food is increased, the enzymatic reactions rate gets increased. Thus, by controlling water activity we can check the enzymatic reactions.

2. The non-enzymatic browning is caused by reactions between glucose or fructose and amino group of food and influenced by water activity level. The maximum level of such reaction occurs in samples equilibrated to 0.65 to 0.70 $a_{w.}$ But reduced at higher and lower levels of water activity. Thus, by controlling water activity, we can reduce the non-enzymatic browning.

3. For microbial growth optimum moisture content in food is essential beyond this limit the growth is suppressed. The lower level of water activity does not provide free moisture whereas concentration of solutes suppresses microbial growth. At very high water content dilution of nutrients prevent their growth.

Check Your Progress Exercises 3

1. Properly dried fruits and vegetables should be packed in such packaging materials, which do not permeate moisture vapour, light and gases. These food packages should be stored at desirable relative humidity and temperature. If there are differences in temperature and relative humidity in the packaged food and its surrounding atmosphere, then the moisture migration may cause condensation, which may create problems in the successful transportation. This can be reduced by aeration. Proper packaging also protects food by maintaining desirable water activity.

4.12 SOME USEFUL BOOKS

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3. Troller, J.A. and Christian, J.H.B. (1978) Water Activity and Food. Academic Press, New York.

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UNIT 5 DRYING, DEHYDRATION AND EVAPORATION

Structure

5.0 OBJECTIVES

After reading this unit, you should be able to:

- describe the mechanisms of drying and dehydration of fruits and vegetables;
- reduce the weight and bulk, and water activity of fruits and vegetables;
- explain various methods and types of evaporation and evaporators used;
- define the microorganisms involved in spoilage of dried products;
- determine the drying and rehydration ratio; and
- evaluate the factors affecting the drying rate of fruits and vegetables.

5.1 INTRODUCTION

Drying or dehydration is accomplished by the removal of water from the fruits and vegetables below a certain level at which enzyme activity and growth of microorganisms are affected adversely. Evaporation is an important unit operation commonly employed to remove water from dilute liquid foods to obtain concentrated products. The dried or concentrated fruit or vegetable product is called as high sugar high acid food or high value low volume food. The dried or concentrated products save energy, money and space in packaging storage and transportation. Dehydration or drying process usually involves heating, in which water is removed from solid or near solid substances. Both drying and dehydration mean the removal of water. The term drying is generally used for drying in the sun, while dehydration is generally used for drying the commodities under the controlled conditions. Evaporation process also involves heating where water is removed from the liquid substance. Evaporation, sometimes also termed as concentration, is different from drying and dehydration, since the final product of evaporation process remains in liquid state. Removal of water from food provides microbiological stability and assists in reducing transportation and storage costs. Fruit juice is concentrated by evaporating water. For aromatic juice, it is desirable to heat the juice for short time and cooling rapidly. This minimizes the effect on flavour, aroma, and sugar compounds.

5.2 DRYING PHENOMENA

You are aware that the fruits and vegetables contain sufficient water which allows their spoilage by microorganism and physiological changes. So, the reduction of free water or removal of moisture becomes necessary to provide stability to a product. The drying or dehydration reduces the amount of available moisture, i.e., water activity. The relationship between moisture and solid in fruits sand vegetables is a complex phenomenon. The physiological structure of most fruits and vegetables restricts the rate of migration of water from within to the exposed outer surfaces from where it can evaporate.

Therefore, the changes during dehydration can be explained in terms of heat and mass transfer phenomena. During dehydration a food loses moisture from its surface and gradually develops a dry layer with remaining moisture confined to its centre. A stabilised moisture gradient is formed from the centre to the surface. As a result, the outside dry layer forms an insulation barrier against rapid heat transfer into the food pieces, especially since the evaporating water leaves air voids behind it. In addition to less driving force from decreased heat transfer, the centrally remaining water also has to travel further to get out of the food piece than did surface moisture at the start of drying. And, as the food dries it approaches its normal equilibrium relative humidity, as it does it begins to pick up molecules of water vapour from the atmosphere as fast as it loses them. When these rates are equal drying ceases. The cracking, shrivelling and shrinking may occur during dehydration due to the removal of moisture through diffusion from centre to outer surface. Excessively fast removal of moisture from outer layers may result in case hardening thereby sealing the surface and causing inadequate drying in the centre.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Differentiate between drying and dehydration.

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2. Define evaporation.

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3. What are the main objectives of drying?

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4. How the out side of the product forms a dried layer during drying?

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5.3 FACTORS AFFECTING DRYING

Food dehydration involves two steps (i) to get heat into the product and (ii) to get moisture out of the product. The above two steps are not always favoured by same operating conditions. For example, food may be pressed between two heated plates. This will provide close contact and improve heat transfer into the food through top and bottom, but the close contact of the plates will interfere with the escape of free moisture. Therefore, it may be better to use one bottom hot plate to get heat in and a free surface on top of the food to let moisture out. The following factors influence the drying rate.

i) Temperature

The rate of heat transfer into the food, which provides the driving force for moisture removal, is affected by the temperature difference between heating medium and the food. Greater the temperature difference, more will be the transfer of heat and moisture removal. When the heating medium is air, temperature also plays a role in carrying away the water driven from the food in the form of water vapour. However, moisture creates a saturated atmosphere at the food's surface which slows down the rate of subsequent water removal.

ii) Surface area

The heat and mass transfer is affected by surface area. Higher surface area results into increased rate of drying. Therefore, the food to be dehydrated is sub divided into small pieces or thin layers which speeds up drying for two reasons. First, larger surface area provides more surface in contact with the heating medium and thus, more surface area from which moisture can escape. Second, smaller particles or thin layers reduce the distance through which heat travels to the centre of the food and moisture in the centre of the food travels to reach the surface and escape.

iii) Air velocity

High velocity air, in addition to taking up moisture, sweeps it away from the drying food surface. It also prevents the moisture from making a saturated atmosphere around food and hence helps in subsequent moisture removal.

iv) Dryness of the air

When the food is dried in air, food drys rapidly due to higher absorption and more holding capacity of moisture by dry air than the moist air. Moist air is closer to saturation so can absorb and hold less additional moisture,

The extent of dryness of the air also determines how a low moisture content food can be dried further. Dehydrated food is hygroscopic and each food has its own equilibrium relative humidity. Equilibrium relative humidity (ERH) is the humidity at a given temperature where the food neither loses moisture nor picks up moisture from the atmosphere.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain why it is necessary to use bottom plate as hot and free surface on top during drying of a food.

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2. Describe the role of temperature in drying.

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3. How the higher surface area affects the drying rate?

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4. How the product size affects the drying rate?

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5. What is the role of air in drying?

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6. Define ERH.

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5.4 DRYING AND RECONSTITUTION RATIO

5.4.1 Drying Ratio

Drying ratio varies with the type of variety, growing conditions, time of harvest, grade of raw material and loss in preparation. It should not be expressed on the basis of moisture per cent in the material, rather it should be expressed on a dry weight basis, i.e., as the ratio of water content to dry matter. The weight of dry matter going into the dryer remains the same as that is taken out, i.e., only the amount of water changes, while the dry matter does not. Drying ratio is also known as dehydration ratio.

Knowing the water content of a fresh material entering the dryer and of the product leaving the dryer, the drying ratio, or its reciprocal drying yield, can be calculated as follows:

$$\text{Drying ratio} = \frac{\text{Weight entering dryer}}{\text{Weight leaving dryer}} = \frac{100 - M1}{100 - M0} = \frac{T0 + 1}{T1 + 1}$$

Where M0 = per cent moisture of the material entering the dryer
M1 = per cent moisture of the product leaving the dryer
T0 = lb of water per lb of bone (dry material entering the dryer)
T1 = lb of water per lb bone (dry material leaving the dryer)

For example, potatoes, prepared and ready for the dryer, have about 78 per cent moisture, when properly dried they have about 7 per cent moisture. Then

M0 = 78, M1 = 7, T0= 78/22 = 3.55, T1 = 7/93 =0.075

$$\text{Drying ratio} = \frac{100 - 7}{100 - 78} = \frac{3.55 + 1}{0.075 + 1} = 4.23 = 4.23:1$$

$$\text{Drying yield} = \frac{100 - 78}{100 - 7} = \frac{0.075 + 1}{3.55 + 1} = 40.236 \text{ or } 23.6 \text{ percent}$$

It should be noted that over all ratio between weight of raw material entering the dryer and weight of finished product leaving it must take into consideration the losses incurred during preparation and final inspection.

5.4.2 Reconstitution Ratio

Reconstitution (rehydration) means the replinishment of quantity of water replaced by dehydrated foods.

Calculation can be made to express the results in terms of "rehydration ratio", "coefficient of rehydration" and "per cent of water in the rehydrated material",

Examples of such calculations are as follows:

i) Rehydration ratio

Suppose the weight of the dehydrated sample used for the test is 10 g (W_D) and the drained weight of rehydrated sample is 60 g (WR). Then

$$\text{Rehydration} = \frac{W_R}{W_D} = \frac{60}{10} = \frac{6}{1},$$ The rehydration ratio is 6 to 1, i.e. 6:1

Coefficient of rehydration

The drained weight of the rehydrated sample is 60 g (W_R), the weight of the dehydrated sample is 10 g (W_D) which contains 5 per cent moisture, and the original material before dehydration contained 87 per cent moisture (A). Then, coefficient of rehydration is

$$\frac{W_R \times (100 - A)}{(W_D - W_M)100} = \frac{60 \times (100 - 87)}{\{10 - (10 \times 0.05)\}} = \frac{780}{9.5} = 0.82$$

Where W_M = Weight of dehydrated sample x moisture per cent
or amount of moisture present in dried sample taken

Per cent of water in rehydrated material

Knowing the drained weight of the rehydrated sample, the per cent of water in the rehydrated material can be calculated by

$$\frac{\begin{matrix}\text{Drained wt. of (WR)} \\ \text{rehydrated sample}\end{matrix} - \begin{matrix}\text{Dry matter content in sample} \\ \text{taken for rehydration}\end{matrix}}{\text{Drained wt. of rehydrated material}} \times 100$$

$$\frac{60-9.5}{60} \times 100 = \frac{5050}{60} = 84.1\%$$

Note: It is suggested that the following conditions be met for better rehydration.

1. Determine the time of soaking and boiling that is compatible with optimum quality of the product.
2. Start the test with at least enough water to submerge the pieces, but do not use so much water that excess amount are present at the end of the test.
3. Shake or stir if necessary to insure wetting of all pieces during the test.
4. Control the rate of heating so as to prevent rapid and variable losses of water while boiling.

5.4.3 Rehydration of Dried Fruits and Vegetables

Factors that affect rehydration process of the dehydrated/ dried products are time, temperature, air displacement, pH and juice strength. Rehydration rates can be accelerated by ultrasonic treatment of the product to be rehydrated in water. Gamma radiation increases the rehydration rates of freeze dehydrated apples. In addition, it can control microbial growth subsequently to dehydration and during storage. At 26°C, freeze dried mushrooms rapidly reach the maximum rehydrability. While at 98°C, the rate of rehydration is slower and the degree of rehydration is also lower.

5.5 SPOILAGE OF DRIED FRUITS AND VEGETABLES

A food is said to be spoiled if it has been damaged or injured so as to make it undesirable for human use. "A product is unfit as a food if discriminating consumer, knowing the story of its production and seeing the material itself, will refuse it as a food". Obviously the fitness of the food may be subjective but in dried fruits (apple, apricot, dates, figs, peaches, prunes, resins, etc.) a number of microorganisms can be present. In whole dried fruits, these may vary from a few hundred per gram of fruit to thousands. Due to decreased water activity (<0.65 in case of sun dried product), heat treatment during dehydration and fumigation, the microorganisms may be killed or are unable to cause spoilage. But spores of bacteria and moulds are likely to be numerous. Dried fruits may be spoiled due to the development of rancidity as concentrated flavonoids may undergo oxidation.

Dried or partially dried fruits such as dates, figs and prunes, are susceptible to spoilage by yeast, i.e., *Zygosaccharomyces*. In dates, spoilage may occur if moisture level exceeds 23-25%. In prunes (18-20% moisture), *Monascus bisporus* has been found to be the most frequent spoilage microorganism. Attempts to provide very tender and more palatable products have resulted in 26-28% moisture in prunes, which are highly susceptible to spoilage and require chemical preservative. The shelf –life of high moisture prunes may be extended by dipping them in 2% potassium sorbate or 0.1% sodium benzoate solution.

In dried vegetables, microbial counts are usually higher than fruits and can be a few millions per gram. During drying, if trays are not loaded properly, higher microbial contamination can occur. During blanching also, if the water is not properly chlorinated, infection can occur. The main genera responsible for spoilage are *Escherichia, Bacillus, Clostridium, Micrococcus, Pseudomonas, Streptococcus, Lactobacillus, Leuconostoc* etc.

Another reason for the spoilage of low moisture food (dried/ powdered fruits or vegetables, chips, etc.) is the presence of oxygen, light, relative humidity and higher temperature. At very low water activity ($a_w < 0.1$), no microbial or non-enzymatic spoilage can occur except lipid oxidation. At a_w between 0.2-0.6, only non enzymatic browning can occur. Enzymatic deterioration starts if water activity exceeds 0.3. Mould and yeast activities usually start at $a_w > 0.7$ but bacterial growth is apparent at $a_w \leq 0.8$. The rate of reaction also depends upon temperature (in general, for every 10^0C increase in temperature, the rate of reaction is doubled). Dried apricots treated with SO_2 and stored at different temperatures showed that the samples stored at 46.1°C darkened in 3 weeks but those stored at room temperature (21.1°C) did not darken for 3 months, while those stored at 0°C showed no darkening even after 6 months.

Dried fruits and vegetables are also prone to insect attack if not dried and stored properly. Insects not only consume food stuff but also leave much debris which spoils the appearance of the product. These insect can be killed either by heating or by fumigation. In heat treatment, dried fruits are dipped in boiling water or in dilute solution of salt (NaCl, $NaHCO_3$) and then, redried at 54-65°C. Dried vegetables may be heated directly without preliminary dipping. Fumigation with ethylene oxide inside the storage chamber also reduces attack by insects.

Preventive measures for spoilage

It is desirable to keep the initial microbial contamination as low as possible. To check the growth of microorganisms or prevent the dried fruit and vegetable products from spoilage, the following points should be considered.

- All efforts should be made to apply the appropriate preservative technique, keeping in view the various steps i.e., recommended quantity of preservative, suitable pre-treatments and drying temperature for specific time.
- Mechanical disruption of tissues in the processed product should not occur.
- Equipment used for handling should be clean and free from contamination. As far as possible, contamination from the soil micro flora be avoided. Dipping of fruits and vegetables in solution of chlorine (50-125 ppm) removes the adhered micro flora.
- Inhibition of microbial growth can be achieved by storing the food at low temperature or in an inert atmosphere packaging.
- Any canned product showing bulging or popping should be rejected.
- Any juice or squash or such product showing any cottony type material on the surface of juice should be discarded.

- If a product in a can after opening gives off-flavour, like rotten eggs, alcoholic smell or gas formation, contents of the can should not be consumed.
- Low temperature storage helps in restricting physiological activities.
- It is absolutely essential that the environment of packing of a processed product should be microbe-free or least contaminated.
- The quality of water (both chemical and microbial) is the single –most factor which controls the quality of the finished product. It should conform to the prescribed standards of microbiological (indicator microorganisms) and chemical quality.
- The spoilage of canned product can be minimized especially leakage by regularly checking the equipment used in canning (reformers, flinger, double seamer, retort).
- The quality of raw material used has profound influence on the spoilage behaviour of processed product, e.g. sulphur sugar which blackens the canned fruits and vegetables should be avoided.
- Use of lacquered can prevents sulphur staining or hydrogen swell encountered in canned pertinacious or high acid products, respectively.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between drying and reconstitution ratios.

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2. What are the factors which affect the reconstitution ratio?

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3. What do you mean by spoilage of food?

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5.6 DRYING METHODS AND EQUIPMENT

There are numerous methods of drying and accordingly large number of driers are available commercially. The method of drying and equipment depend on the food material to be dried, i.e., solid, mixture or liquid. Sometimes, drying methods is unique to a product. The factors considered for a drier include method of heat transfer, source of energy radiation and method of heat application. Most of the commercial driers are insulated to reduce heat losses, and hot air in them is recirculated to save energy. The driers and available having energy saving devices which recover heat from the exhaust air or automatically control the air humidity. Some of the driers and drying methods are described below.

5.6.1 Hot Air Driers

i) Sun and solar drying

Sun drying is the most widely practised fruit and vegetable processing operation, particularly in tropical and subtropical regions, where plenty of sunshine is available. The food material is simply laid out on flat surfaces and turned regularly until dry. In solar drying system, solar energy is collected in a chamber to heat the air, which in turn dries the material. The solar driers may be direct, indirect or mixed of energy collectors.

Both these drying methods are simple and inexpensive. However, the disadvantages of drying food material by these methods are poor control over dying conditions and lower drying rates. This results in lower quality and variability in the dried product.

ii) Kiln driers

These driers are two storey constructions. A furnace on the lower floor generates heat and the warm air rises to upper storey which has a slotted floor. The food such as apple slices or rings are spread over the slotted floor for drying. In this method drying time is relatively longer and there is no control over drying conditions. Therefore, it has limited use. However, the driers have a large capacity and are easy to maintain.

iii) Cabinet driers (tray driers)

These driers consists an insulated cabinet fitted with stainless steel trays. These trays may be of shallow mesh or perforated. A cabinet drier may contain 6 to 96 trays or more depending on use. The heat in these driers may be generated by electricity or through a furnace fired with diesel, petrol or kerosene oil. The food is spread in thin layers (2-6 cm deep) on the trays. Hot air is circulated over and / or through each tray by a system of ducts and baffles for uniform air distribution. Tray driers are used for small scale production (1-20 t/day) or for pilot scale work. They have low capital and maintenance cost.

iv) Conveyor or belt driers

In these driers fruits and vegetables are dried on a mesh belt. Initially the air flow is directed upwards through the bed of food and later on downwards. In two or three stage driers, the food material may be dried into deeper beds (15-25 cm to 250-900 cm thickness). The product is dried uniformly to 10-15 per cent moisture level. In these driers drying conditions can be controlled easily and production rates are usually higher.

v) Tunnel driers

These driers are used for large scale (up to 5000 kg) drying of food material. Thin layers of food are spread on trays and stacked on carts/trucks which move through an insulated hot tunnel. When a dry cart leaves the discharging and of the tunnel it makes room to load another wet cart into the receiving end of the tunnel. The food dehydration in these driers is a semi-continuous process. The drying of food is finished in bin driers as these driers lower the moisture content of semi dried food to 3-6 per cent level.

vi) Belt though driers

These are air convection belt driers used for small and uniform pieces of fruits and vegetables. The food is dried in a mesh conveyor belt which hangs freely between rollers, to form a shape of a trough. The heated air is blown through the bed of food. The belt moves keeping the food pieces in the trough in constant motion to expose new surfaces continuously to hot air. The mixing action moves food away from the drying air thus, allowing time for moisture to move from the interior of the pieces to the dry surface. The moisture removes rapidly. The drier operates in two stages, first to 50-60 per cent moisture and then to 15-20 per cent moisture level. Foods are finished in bin driers. These driers are not suitable for sticky foods.

vii) Bin driers

These are cylindrical or rectangular containers fitted with a mesh base. Hot air passes up through a bed of food at relatively low speeds. They are usually used for finishing (3-6% moisture level) after initial drying in other types of driers. These driers have a high capacity and low capital and running cost.

viii) Fludised bed driers

In these driers hot air is blown through a food bed contained in metal trays with mesh or perforated bases. The greater air velocities make the bed expand, and the food particles become suspended in air and vigorously agitated. The bed is said to be fludised. The air thus acts as with the drying and the fludising medium. Fludising is a very effective way of maximising the surface area of food for drying in a relatively small space. Driers may be batch or continuous in operation. These driers are compact and have good control over drying conditions, high thermal efficiencies and high drying rates. Fludised bed driers are limited to small particulate foods that are capable of being fludised without excessive mechanical damage (e.g., peas, diced or sliced vegetables, powders).

ix) Spray driers

These are air convection driers used for dehydrating liquid food products. In these driers, a fine dispersion of pre concentrated liquid food is first atomized to form droplets (10-200 μm diameter) and sprayed into a current of heated air at 150-300^{0}C in a large drying chamber. The dry particles, suspended in air stream, flow into separation equipment where they are removed from air, collected, and packaged or subjected to further treatment such as instantising. For successful drying uniform atomising is necessary which may be achieved by centrifugal or pressure nozzle or two-fluid nozzle atomizers.

5.6.2 Heated Surface Driers

In these driers heat is supplied to the food material by conduction. These driers have two advantages over hot air driers.

i) large volume of air is not required to be heated before drying commences,
ii) drying may be carried out in the absence of oxygen.

i) Drum or roller driers

The driers may have a single or double or twin hollow drums. The single drum is widely used. In these driers slowly rotating hollow steel drums are heated internally by pressurized steam (120-170°C). A thin layer of food (paste, puree or sludge) is spread uniformly over the outer surface by dipping, by spraying, by spreading or by auxiliary feed rollers. Before the drum has completed one revolution (within 3 minutes), the dried food in the form of thin layer is scraped off by a 'doctor' blade which contacts the drum surface uniformly along its length. The driers have been used successfully to dry apple sauce, purees of apple, banana, mango, papaya, etc.

ii) Vacuum band and vacuum shelf driers

These driers are used to produce puff dried foods. In vacuum band drier a food slurry is spread or sprayed onto a steel belt (or band) which passes over two hollow drums within a vacuum chamber. The food is first dried by steam heated drum and then by steam heated coils located over the band. The dried food is cooled by a second water-cooled drum and removed by a doctor blade. Vacuum shelf drier consists of hollow shelves in a vacuum chamber. Food is placed in thin layers on flat metal trays and vacuum is created in the chamber. Hot air or steam is passed to dry the food.

5.6.3 Freeze Drying

Dehydration by freezing (lyophilization) requires a product to be first frozen in a conventional freezer and then evaporating (sublimating) the water, which is in ice form, directly into the vapour phase at a very low temperature (up to –80°C) and pressure. Freeze driers consist of a vacuum chamber which contains trays to hold the food material during drying, and heaters.

Refrigeration coils are used to condense the vapours. Automatic defrosting devices are fitted alongside to keep the coils free of ice for vapour condensation. Vacuum pumps remove non condensable vapours. The types of driers depend on supply of heat to food. Commercially, conduction and radiation types are used. Different type of freeze driers are contact freeze driers, accelerated freeze driers, radiation freeze driers, microwave and dielectric freeze driers, liquid nitrogen and cryogenic freezing.

5.6.4 Osmotic Drying

The process of osmotic drying is the removal of a percentage of water from a piece of fruit or vegetable by placing it in contact with granular sugar / salt or a concentrated sugar / salt solution. About 40 per cent of the water can be removed by this process. After osmotic dehydration, the product may either be frozen, or dried in air or vacuum drier. The time and temperature of osmotic dehydration depend on the size, shape and the food material. Sometimes, sulphur dioxide treatment is required to preserve the colour. This process is comparatively costlier than conventional drying.

5.6.5 Microwave Drying

Microwave is a form of electromagnetic energy. They are transmitted as waves, which penetrate food material, and are then converted to heat. Microwaves are produced at specific frequency bands. When microwaves are passed into a food material they induce friction in water molecules and produce heat. The extent of heating depends on the water content of the food material. Domestic and commercial microwave ovens are available which may be used to dry fruit juices, pulps, fruit pieces, etc.

5.6.6 Foam Mat Drying

The process is used to dry liquid foods. They are formed into a stable foam by the addition of a stabilizer or a foaming agent and aeration with nitrogen or air. The foam is spread on a perforated belt/tray to a depth of 2-3 mm and dried rapidly in a drier. Foam drying is approximately three times faster than drying a similar thickness of liquid. The thin porous mat of dried liquid is ground to a free flowing powder. The rapid drying and low product temperatures result in a high quality product.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the important methods of drying?

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2. Explain what you understand by freeze drying?

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3. What is microwave drying?

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5.7 EVAPORATION/CONCENTRATION METHOD AND EQUIPMENT

Liquid foods are usually concentrated by partial removal of water through evaporation. Function of evaporation is to pre-concentrate the food prior to drying, freezing or sterilization. It increases the solids content and reduces the weight and volume of a food. During evaporations, latent heat is transferred from the heating medium (steam) to the food, to raise the temperature of its boiling point. The vapour pressure rises and bubbles of vapour in the liquid are formed due to latent heat of vaporization supplied by the steam. The vapour is then removed from the surface of the boiling liquid. The more common concentrated foods include fruit and vegetable juices and concentrates jams and jellies, tomato paste, fruit purees, etc. Some of the methods and equipment for evaporation or concentration of foods are described below.

5.7.1 Methods of Evaporation

i) Solar evaporation

Solar evaporation is the simplest method of evaporating water with solar energy. This was done to derivate salt from sea water from earliest times and is still practiced. However, solar evaporation is very slow and is suitable only for concentrating salt solutions.

ii) Open kettles

Some foods can be satisfactory concentrated in open kettle that is heated by steam. This is the case for some jellies and jams and for certain types of soups. However, high temperatures and long concentration times damage most foods. In addition, thickening and burn-on of product to the kettle wall gradually lower the efficiency of heat transfer and slow the concentration process. Kettles and pans are still widely used in the manufacture of maple syrup, but here high heat is desirable to produce colour from caramelized sugar and to develop typical flavour.

iii) Flash evaporators

Flash evaporators are used for subdividing the food material and bringing it into direct contact with the heating medium. Clean steam superheated at about 150°C is injected into food which is pumped into an evaporation tube where boiling occurs. The boiling mixture then enters a separator vessel in which the concentrated food is drawn off at the bottom and the steam plus water vapour from the food is evacuated through a separate outlet. Because temperatures are high, foods that lose volatile flavour constituents will yield these to the exiting steam and water vapour. These can be separated from the vapour by essence-recovery equipment on the basis of different boiling points between the essence and water.

iv) Thin-film evaporators

In thin-film evaporators, food is pumped into a vertical cylinder which has a rotating element that spreads the food into a thin layer on the cylinder wall. The cylinder wall of double jacket construction usually is heated by steam. Water is quickly flashed from the thin food layer and the concentrated food is simultaneously wiped from the cylinder wall. The concentrated food and water vapour are continuously discharged to an external separator; from which product is removed at the bottom and water vapour passes to a condenser. In some systems the water vapour temperature is raised by mechanical vapour recompression to yield steam for reuse to save energy. Product temperature may reach 85°C or higher, but since residence time of the concentrating food in the heated cylinder may be less than a minute, heat damage is minimal.

v) Vacuum evaporators

Heat-sensitive foods are most commonly concentrated in low temperature vacuum evaporators. Thin-film evaporators frequently are operated under vacuum by connecting a vacuum pump or steam ejector to the condenser.

It is common to construct several vacuum vessels in series so that the food product moves from one vacuum chamber to the next and thereby becomes progressively more concentrated in stages. The successive stages are maintained at progressively higher degrees of vacuum, and the hot water vapour arising from the first stage is used to heat the second stage. The vapour from the second stage heats the third stage, and so on. In this way, maximum use of heat energy is obtained. Such a system is called a multiple effect vacuum evaporator. System employed in grape juice industry continuously concentrate juice from an initial solids content of 15% to a final solid concentration of 72% at rate of 4500 gal of single strength juice per hour. Similar systems concentrate tomato juice from 6% solids to 30% solids at rate of 15,000 gal or more of single strength juice per hour. Use of energy-saving mechanical vapour recompression is common.

vi) Freeze concentration

When a solid or liquid is frozen, all of its components do not freeze at once, some of the water forms ice crystals in the mixture. The remaining unfrozen food solution is now higher in solid concentration. It is possible, before the entire mixture freezes, to separate the initially formed ice crystals. One way of doing this is to centrifuge the partially frozen slush through a fine mesh screen. The concentrated unfrozen food solution passes through the screen while the frozen water crystals are retained and can be discarded. Repeating this process several times on the concentrated unfrozen food solution can increase its final concentration several- fold. Freeze concentration has been applied commercially to orange juice.

vii) Ultra filtration and reverse osmosis/hyper filtration

Low-temperature separation and concentration processes employing perm selective membranes are increasingly being used in the food industry. These applications are largely dependent on membrane properties such as water permeability rate, solute and macromolecule rejection rate, and length of useful membrane life. Different membranes are required for different liquid foods.

There are two types of pressure-driven membrane separation processes, a) reverse osmosis / hyper filtration, and b) ultra filtration. In the former, macromolecular solutes are selectively removed, whereas the latter separates out relatively larger solute molecules or colloids. Ultra filtration membranes are generally " less tight" than reverse osmosis membranes, that is, they restrict macromolecules such as proteins but with moderate pressure allow smaller molecules such as sugar and salt to pass through. Reverse osmosis membranes are "tighter" and with greater pressure will permit the passage of water but hold back various sugars, salt, and larger molecules. In nature, osmosis involves the movement of water through a perm-selective membrane from a region of higher concentration to a region of lower concentration; the region of lower concentration generally contains solutes in solution and has associated with it an osmotic pressure. It is possible to reverse the normal flow of water through the membrane by applying pressure on the solute side flow of water through the membrane by applying pressure on the solute side of the membrane in excess of the osmotic pressure. This is a reverse osmosis.

viii) Plate evaporator

Plate evaporator is similar to plate heat exchanger. The fluid which is to be evaporated is passed on one side of the plate and steam flows on the other side. The fluid is superheated and passes into a flash chamber. The evaporator flashes-off and the product and vapours are separated. High viscosity fluids can be efficiently circulated in the evaporators with concentration above 60°Brix.

ix) Membrane concentration

A high quality product can be produced by membrane concentration process. The principle involved is the interposition of a membrane between the food stream and a waste or transfer stream, and the establishment conditions providing a driving force for transport of water across the membrane from the feed to the transfer stream. The possibility of obtaining high quality product depends on the use of semi-permeable membranes which means membranes with much less resistance to water transport than to transport of components that are to be retained.

Ostomek is a new process and is a cold direct osmotic concentration process, utilising a thin membrane (25-10 μm) with a molecular weight cut-off of about 100 daltons. High fructose corn syrup is used as an agent to facilitate osmotic concentration as it flows, counter-current to the juice. Heat labile juice such as strawberry would benefit from this cold process, since flavour and colour degrade with exposure to heat. Concentration of clear juice streams are also possible using a continuation of reverse osmosis and evaporation. Cross flow membrane systems are ideally suited for this application because of self cleaning turbulence effect. The reverse osmosis technology is effective in concentrating a low solids juice (7-8°B) two or three folds.

x) Centrifugal evaporators

In these evaporators, a thin film is produced by centrifugal force in single or nested cones. The cones have steam on the alternative side to provide a heat transfer surface. The system operates under vacuum. This allows the total time on the juice transfer surface to be as little as 0.5 second, with only a small increase in product temperature. They are good for extremely heat sensitive and or high viscosity products. Their major draw back is low capacity and high capital cost. These evaporators concentrate as well as distil de-gas and de-odourize the liquids that have high sensitivity to heat.

5.7.2 Types of Evaporators

Several types of evaporators are used in the food industry.

i) Batch-type pan evaporator

One of the simplest and perhaps oldest types of evaporators used in the food industry is the batch-type pan evaporator. The product is heated in a steam jacketed spherical vessel. The heating vessel may be open to the atmosphere or connected to a condenser and vacuum. Vacuum permits boiling of the product at temperatures lower than the boiling point at atmospheric pressure, thus reducing the thermal damage to heat-sensitive products.

The heat-transfer area per unit volume in a pan evaporator is small. Thus, the residence time of the product is usually very long, up to several hours. Heating of the product occur mainly due to natural convection, reducing in smaller convective heat transfer coefficients. The poor heat transfer characteristics substantially reduce the processing capacities of the batch type pan evaporator.

ii) Natural circulation evaporators

In natural circulation evaporators, short vertical tubes, typically 1-2m long and 50-100 mm in diameter, are arranged inside the steam chest. The whole calamari (tubes and steam chest) is located in the bottom of the vessel. The product when heated rises through these tubes by natural circulation while steam condenses outside the tubes. Evaporation takes place inside the tubes and the product is concentrated. The concentrated liquid falls back to the base of the vessel through a central annular section.

iii) Rising-film evaporator

In a rising-film evaporator a low viscosity liquid food is allowed to boil inside 10-15 m long vertical tubes. The tubes are heated from the outside with steam. The liquid rises inside these tubes by vapours formed near the bottom of the heating tubes. The upward movement of vapours cause a thin liquid film to move rapidly upwards. A temperature difference of at least 14°C between the product and the heating medium is necessary to obtain a well developed film. High convective heat –transfer coefficient is achieved in these evaporators. Although the operation is mostly once through, liquid can be recirculated if necessary to obtain the required solid concentration.

iv) Falling-film evaporator

In contrast to the rising- film evaporator, the falling film evaporator is used for high viscous liquids. Film moves downwards under gravity on the inside of the vertical tubes. The design of such evaporator is complicated by the fact that distribution of liquid in a uniform film flowing downwards in a tube is more difficult to obtain than an upward-flow system such as in a rising film evaporator. This is accomplished by the use of special designed distributors or spray nozzles. The falling-film evaporator allows a greater number of effects than the rising film evaporator. For example, if steam is available at 110°C and boiling temperature in the last effect is 50°C, then the total available temperature differential is 60°C. Since rising film evaporator requires 14°C temperature differential across the heating surface, only four effects are feasible. However, as many as 10 or more effects may be possible using a falling-film evaporator. The falling-film evaporator can handle more viscous liquid than the rising film type. This type of evaporator is best suited for high heat-sensitive products such as orange juice. Typical residence time in a falling film evaporator is 20-30 seconds compared with a residence time of 3-4 minutes in a rising film evaporator.

v) Rising/falling-film evaporator

In the rising /falling film evaporator, the product is concentrated by circulation through a rising-film section followed by a falling-film section of the evaporator. The product is first concentrated as it ascends through a rising tube section, followed by the pre concentrated product descending through a falling-film section, there it attains its final concentration.

vi) Forced-circulation evaporator

The forced circulation evaporator involves a non contact heat exchanger where liquid food is circulated at high rates. A hydrostatic head, above the top of the tubes, eliminates any boiling of the liquid. Inside the separator, absolute pressure is kept slightly lower than that in the tube bundle. Thus, the liquid entering the separator flashes to form a vapour. The temperature difference across the heating surface in the heat exchanger is usually 3-5°C. Axial flow pumps are generally used to maintain high circulation rates with linear velocities of 2-6 m/s, compared with a linear velocity of 0.3-1 m/s in natural-circulation evaporators. Both capital and operating costs of these evaporators are very low in comparison to other types of evaporators.

vii) Agitated thin-film evaporator

It is used for very viscous fluid foods. The feed is spread on the inside of the cylindrical heating surface by wiper blades. Due to high agitation, considerably higher rates of heat-transfer are obtained. The cylindrical configuration results in low heat transfer area per unit volume of the product. High pressure steam is used as the heating medium to obtain high wall temperatures for reasonable evaporation rates. The major disadvantages are the high capital and maintaining costs and low processing capacity.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Explain evaporation and concentration of fruit juices.

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2. How the solar evaporation is different from kettle evaporation.

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3. How the osmosis process is different from reverse osmosis.

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4. What are drawbacks of centrifugal evaporator?

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5. What are types of evaporator?

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6. How falling film evaporator is different from rising film evaporator.

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7. What are major disadvantages of agitated thin film evaporator?

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5.8 LET US SUM UP

Removal of water from food is primarily done to lower the water activity (a_w) so that microbial growth is inhibited. It also saves energy, moisture and space in shipping, packaging, storage and transportation of dried fruit and vegetable products, which are known as high value low volume food or high acid high sugar foods. Dehydration industry is a processing industry of the future. There exists quite a good scope for the export of dehydrated fruits and vegetables as the demand for these products is on the rise in the world, particularly in European countries. It is, therefore, necessary to co- ordinate effectively and achieve all that is possible in the field of export, internal demand, right quality and variety of raw material, product promotion, new technologies, etc., with the objective of helping the grower to get remunerative returns for his produce. Evaporation is an important unit operation commonly employed to remove water from dilute liquid foods to obtain concentrated liquid products which provides microbiological stability and assists in reducing transportation and storage costs.

Due to decreased water activity (<0.65 in case of sun dried product), microorganisms may be killed or are unable to cause spoilage in dehydrated products. But spores of bacteria and moulds are likely to be the most numerous. Dried fruits may be spoiled due to the development of rancidity as concentrated flavonoids may undergo oxidation. It is desirable to keep the initial microbial contamination as low as possible and the commodities should be handled and stored in such a way that there are minimum chances of further contamination.

5.9 KEY WORDS

Water activity : Water activity (a_w) is the ratio of vapour pressure of food (p) and pure water (p_o) and expressed by aw = p/p_o.

Sorption isotherms : Water sorption isotherm is a graphical presentation of data which shows the water relationship of food.

Concentration : Removal of water from foods mostly by heat application and concentration of soluble solids or solutes.

Preservation : Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutritious and free from microbial infection.

ERH : Equilibrium relative humidity.

Osmosis : Osmosis means movement of water through a membrane from higher concentration to lower concentration.

Unit operation : It is a step in the complete process or a physical change in form or place, for example, peeling, cutting, grading, etc.

Drying ratio : Drying ratio is the reciprocal of fresh material to dried material.

Spoilage : The food which has been damaged or injured make the food undesirable for human use.

Rehydration ratio : Reconstitution ratio is the quantity of water absorbed by dehydrated foods.

Reverse osmosis : Reverse osmosis means movement of water through the membrane by applying pressure on the solute side of the membrane in excesses of the osmotic pressure.

Evaporation : Evaporation is a heating process in which water is removed from the liquid substance.

5.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Drying of a commodity in the sun with non conventional sources of energy like sun and wind.
   - Drying a commodity under controlled conditions like temperature, relative humidity and air flow.

2. Your answer should include the following points:
   - An unit operation commonly employed to remove water from liquid foods.
   - To obtain concentrated liquid products.

3. Your answer should include the following points:
   - To reduce the weight and bulk of a food.
   - To reduce the water activity.

4. Your answer should include the following points:
   - Due to loss of moisture from the surface.
   - Stabilizing the moisture gradient between surface and centre of the product.

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - To get heat in.
   - To let moisture out.

2. Your answer should include the following points:
   - It provides the driving force for moisture removal.
   - It carries away water in the form of water vapour.

3. Your answer should include the following points:
   - It provides more surface in contact with heating medium.
   - Provides more surface for moisture removal.

4. Your answer should include the following points:
   - Smaller product size reduces the distance through which moisture is to travel from centre of the surface.
   - Smaller product size reduces the distance through which heat is to be transferred from the surface to the centre.

5. Your answer should include the following points:

   - It absorbs more moisture.
   - It sweeps away moisture very fast.

6. Your answer should include the following points:

   - The relative humidity at which product neither gains nor loses its moisture.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Drying ratio is the reciprocal of fresh material to dried material.
   - Reconstitution ratio is the quantity of water replaced by dehydrated foods.

2. Your answer should include the following points:

   - Time of soaking
   - Temperature of the water
   - Air displacement
   - pH of the product
   - Juice or sugar content availability in the product.

3. Your answer should include the following points:

   - The food which has been damaged or injured.
   - The food which is not fit for consumption.
   - The food which is attacked by microorganisms.

Check Your Progress Exercise 4

1. Your answer should include the following points:

   - Drying the food material by using hot air.
   - Drying the food material by using heated surface.
   - Drying the food material by freezing.
   - Drying the food material by microwaves.
   - Drying the food material by using sugar or salt and their solutions.

2. Your answer should include the following points:

   - Dehydration by freezing means drying a food material at low temperature (up to –80°C) and low pressure.
   - At low temperature and pressure, the water in ice form in food material is evaporated directly into vapour (sublimation).

3. Your answer should include the following points:

   - Microwaves are a form of electromagnetic energy.
   - Microwaves are when passed into a food material they induce friction in water molecules and produce heat, thus drying the material.

Check Your Progress Exercise 5

1. Your answer should include the following points:

   - Removal of water from the liquid substances.
   - Removal of water to concentrate soluble solids.

2. Your answer should include the following points:

   - Solar evaporation is used for salt concentration.
   - Kettle evaporation is used for maple syrup.

3. Your answer should include the following points:

   - Osmosis means movement of water through a membrane from higher concentration to lower concentration.
   - Reverse osmosis means movement of water through the membrane by applying pressure on the solute side of the membrane in excesses of the osmotic pressure.

4. Your answer should include the following points:

   - Low capacity
   - High capital cost

5. Your answer should include the following points:

   - Batch type evaporator
   - Natural circulation evaporator
   - Rising film evaporator
   - Falling/film evaporator
   - Rising/falling film evaporator
   - Forced circular evaporator

6. Your answer should include the following points:

   - Falling film evaporator is used for high viscous liquids, while rising film evaporator is used for low viscous liquids.
   - High heat sensitive products are more suited to falling film evaporator while low heat sensitive products used in rising film evaporation.

7. Your answer should include the following points:

   - High capital and maintenance cost.
   - Low processing capacity.

5.11 SOME USEFUL BOOKS

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UNIT 6 CHILLING

Structure

6.0 OBJECTIVES

After reading this unit, you should be able to:

- describe chilling and refrigeration cycle;
- explain chilling injury and refrigerated requirements of fruits and vegetables; and
- define evaporative cooling.

6.1 INTRODUCTION

You know that fruits and vegetables are highly perishable and more liable to spoilage than food grains. This is basically because they contain high moisture content. The spoilage of such perishable crops can be delayed by controlling the post harvest environmental conditions of temperature, humidity and atmospheric concentration of gases. Chilling is one such method of regulating temperature. More precisely, chilling mean the use of low temperature without inducing ice formation in foods. The chilling process may be considered complete when the mean temperature of the product has approximately reached the intended value for storage or processing.

The chilling operation is divided into 3 basic types based on its main purpose.

i) Chilling for preservation.

ii) Chilling for development of desired biological and biochemical processes.

iii) Chilling to facilitate some processing treatments, by temporarily changing certain physico-chemical properties.

Chilling for preservation is aimed to extend the shelf-life or keeping quality of a living produce, e.g., fruits and vegetables. This is mainly due to reduction of metabolic activity at low temperature. Chilling may also be used to extend the storage life of products such as pasteurized and sterilized canned foods.

Chilling for development of desired biological and biochemical processes includes fermentation of beer and wine, meat ageing, and processing of many dairy products such as cheeses, etc.

Temporarily changing certain physico-chemical properties to facilitate some processing treatments is used in the processing of bakery products, chocolate, butter, margarine etc. However, this is beyond the scope of the present unit and we would restrict ourselves to chilling for preservation only. In the present unit, we will focus only on the first purpose, i.e., chilling for preservation.

Refrigeration is the most common method of chilling or low temperature storage of fruits and vegetables. Refrigerated storage helps to retard the spoilage in perishable crops in the following manner:

- aging due to ripening, softening, textural and colour changes;
- undesirable metabolic changes and respiratory heat production;
- moisture loss and the wilting;
- spoilage due to invasion by bacteria, fungi, and yeasts; and
- undesirable growth, such as sprouting of potatoes.

One of the most important functions of refrigeration is to control the respiration of crops. Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavour, loss of saleable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and post-harvest life. The higher the storage temperature, the higher will be the respiration rate. Apart from temperature, humidity and concentration of gases are also important. Before observing their effect let us first understand how refrigerator works.

6.2 REFRIGERATION

The refrigerator cycle is based on the principle of making cold which is done by removing heat from the system. If you are science student then you must have surely studied carnot's engine. Refrigeration is in fact the reverse of carnot's engine. The refrigeration cycle uses a fluid, called a refrigerant, to move heat from one place to another. The key to understanding how it works is recognizing that at the same pressure, the refrigerant boils at a much lower temperature than water. For example, the refrigerant commonly used in home refrigerators boils between 40 and 50°F (4.4 – 10°C) as compared to water's boiling point of 212°F (100°C). In the original home refrigerators ammonia was the common refrigerant used. Pure ammonia gas is highly toxic to people and would pose a threat if the refrigerator were to leak, so all home refrigerators don't use pure ammonia. You might have heard of refrigerants known as **CFCs** (chlorofluorocarbons). These were originally developed by Du Pont in the 1930s as a non-toxic replacement for ammonia. CFC-12 (dichlorodifluoromethane) has about the same boiling point as ammonia. However, CFC-12 is not toxic to humans, so it is safe to use in your kitchen. However, many large industrial refrigerators still use ammonia. In the 1970s, it was discovered that the CFCs then in use are harmful to the ozone layer, so as of the 1990s, all new refrigerators and air conditioners use refrigerants that are less harmful to the ozone layer. Freon is the common refrigerant used today. Now we need to study the refrigeration cycle.

Every refrigerator is made up of at least four key parts:

i) Compressor
ii) Heat-exchanging pipes (also known as a condenser)

iii) Expansion valve
iv) Refrigerant

Let's look at the process to see how boiling and condensing a refrigerant can move heat. The process is the same whether it is operating a refrigerator, an air conditioner or a heat pump. This example illustrates a closed-loop system (Figure 6.1).

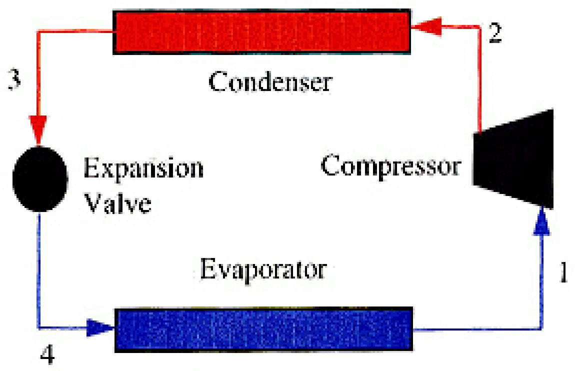


Figure 6.1: Vapour compression refrigeration cycle

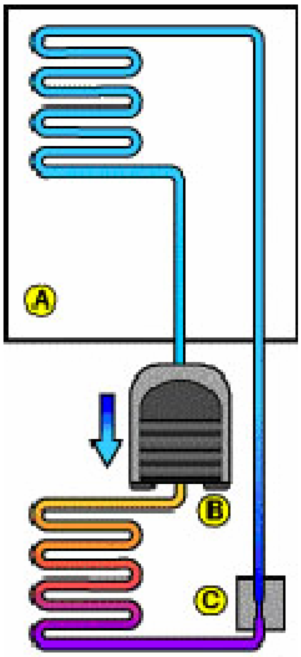
The above diagram shows the simplified, stepwise process of the refrigeration cycle, where the associated parts of the refrigerator fit into it. These four parts will now be explained in detail. Lets begin with evaporator first. As the name implies, refrigerant in the evaporator "evaporates". Upon entering the evaporator, the liquid refrigerant's temperature is between 40 and 50°F and without changing its temperature, it absorbs heat as it changes state from a liquid to a vapour. The heat comes from the warm moist room air blown across the evaporator coil. As it passes over the cool coil, it gives up some of its heat and moisture may condense from it. The cooler drier room air is re-circulated by a blower into the space to be cooled.

The vapour refrigerant now moves into the compressor, which is basically a pump that raises the pressure so it will move through the system. Once it passes through the compressor, the refrigerant is said to be on the "high" side of the system. Like anything that is put under pressure, the increased pressure from the compressor causes the temperature of the refrigerant to rise. As it leaves the compressor, the refrigerant is a hot vapour, roughly 120 to 140°F.

It now flows into the refrigerant-to-water heat exchanger, operating as the condenser during cooling. Again, as the name suggests, the refrigerant condenses here into liquid form. As it condenses, it gives up heat to the loop, which is circulated by a pump. The loop water is able to pick up heat from the coils because it is still cooler than the 120 degree coils.

As the refrigerant leaves the condenser, it is cooler, but still under pressure provided by the compressor. It then reaches the expansion valve. The expansion valve allows the high pressure refrigerant to "flash" through becoming a lower pressure cooled liquid. This pressure drop causes expansion followed by evaporation. Evaporation further causes heat absorption making refrigerant cool. The cycle is complete as the cool liquid refrigerant re-enters the evaporator to pick up room heat. In winter, the reversing valve switches the indoor coil to operate as the condenser and the heat exchanger as the evaporator.

In summary, the indoor coil and refrigerant-to-water heat exchanger where the refrigerant changes phase by absorbing or releasing heat through boiling and condensing. The compressor and expansion valve facilitate the pressure changes, increased by the compressor and reduced by the expansion valve. See a detailed Figure 6.2.



A -- Inside of refrigeration
B -- Compressor
C -- Expansion valve

Figure 6.2: Back panel of a refrigerator

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is chilling?

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2. Where does actual phase change take place in the refrigerator?

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3. What are the common refrigerants used in the refrigerator?

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6.3 DETERMINATION OF REFRIGERATION LOAD

If we want to cool the product then heat must be removed and brought to a specific low temperature. The heat removed is described in terms of refrigeration load. In other words, refrigeration load can be defined as that quantity of heat which must be removed in order to reduce the temperature of the products from its initial temperature to the temperature consistent with good frozen food storage. It is calculated in terms of heat unit as British Thermal Units (Btu), calories (cal) or joules (J). This has, of course, been replaced by International System of Units (SI) which employs joules and gram as units of heat and weight (One Btu = 252 calories = 1055 joules = 1.055 KJ).

One Btu or British Thermal Unit is defined as the quantity of heat which will raise or lower the temperature of one pound of water by 1°F through the range of 32°F to 212°F at normal atmospheric pressure.

A calorie is the amount of heat which will raise or lower the temperature of one gram of water by 1°C from 14.5 to 15.5°C at normal atmospheric pressure.

The specific heat of any substance is the ratio of its heat capacity to that of water. In either case, the specific heat of water is taken as one. Thus, in British system, specific heat is

$$= -\frac{\text{Heat required to raise/lower the temperature of unit mass of water by } 1^{\circ}\text{C}}{\text{Heat required to raise/lower the temperature of unit mass of water by } 1^{\circ}\text{C}}$$

(Since heat capacity of water = 1).

Or, Specific heat at any temperature = Heat required to raise or lower the temperature of unit mass of water by 1°C or in other words, amount of heat in calories required to raise or lower the temperature of one gram of the substance by 1°C.

Generally heat is of two types – Sensible heat and latent heat.

Sensible heat may be defined as the heat we readily perceive by the sense of touch and which produces a temperature rise or fall as heat is added or removed from a substance. Always remember that specific heat is different in the liquid state and in the frozen state. So, it may be different before and after freezing.

Latent heat is the quantity of heat required to change the state or condition under which a substance exists, without changing its temperature, e.g., a definite quantity of heat must be removed from water at 0°C (32°F) to change it to ice at 0°C. This is known as latent heat of fusion or crystallization.

Similarly, in going from water to steam at 100°C, it is the latent heat of evaporation. In freezing, we are interested in the latent heat of fusion, and this in the case of water is 144 Btu/1b. It is quantitatively different from 144 Btu/lb for substances other than water.

Calculation Refrigeration Load

After you have known the terms, let us see how to calculate refrigeration load. To calculate this we need to understand that to freeze a food it is necessary to bring down its temperature to freezing point. This involves the following:

i) The number of Btu required to cool the product from its initial temperature to its freezing point, or say H_1.

ii) The number of Btu required to change the food from the liquid state to the frozen state at its freezing point, or say H_2.

iii) The number of Btu required to lower the frozen food from its freezing point to the desired storage temperature, or say H_3.

Using this concept, we can calculate refrigeration load using the following equations:

$$H_1 = (S_L) \times (W) \times (T_i - T_f) \qquad (1)$$

$$H_2 = (H_f f) \times W \qquad (2)$$

$$H_3 = (S_S) \times W \times (T_f - T_s) \qquad (3)$$

$$H_{fs} = H_1 + H_2 + H_3$$

Where,

S_L = Specific heat of food above its freezing point

H_f = Latent heat of fusion

S_S = Specific heat of food below its freezing point

H_{fs} = Total heat (Btu) requirement

W = Weight in pounds

T_i-T_f = Difference between the initial temperature and the freezing point (°F).

T_f-T_S = Difference between the freezing point and the desired storage temperature (°F).

Let's take one example:

What is Btu requirement to lower the temperature of 1000 lbs of peas from 70°F to 30°F, and finally to storage given at temperature at 0°F. Given S_L =0.8, H_f = 108, S_S = 0.43.

Here we first have to calculate H_1.

From equation (1)

$$H_1 = (S_L) \times (W) \times (T_i - T_f)$$

$$= 0.8 \times 1000 \times (70 - 30)$$

$$= 0.8 \times 1000 \times 40$$

$$= 32000 \text{ Btu.}$$

Now, calculate H_2.

From equation (2)

$$H_2 = H_f \times W$$

$$= 108 \times 1000$$

$$= 108000$$

Finally, calculate H_3.

From equation (3)

$$H_3 = (H_f) \times (W) \times (T_f - T_s)$$

$$= 0.43 \times 1000 \times (30\text{-}0)$$

$$= 12900$$

$$H_{fs} = H_1 + H_2 + H_3$$

$$= 32000 + 10800 + 12900$$

$$= 152900 \text{ Btu.}$$

Refrigeration load is usually reported in terms of refrigeration. So values should be changed to tonnes by dividing Btu by 288000:

$$\frac{152000}{288000} = 0.527 \text{ tonnes}$$

One ton (2000 1b) of refrigeration is the number of Btu required to convert 1 ton of water at 32°F to 1 ton of ice at 32°F in 24 hrs. Since latent heat of fusion for water = 144 btu/lb, a ton of refrigeration = 144 × 2000 = 288,000 Btu/24 hrs.

6.4 REFRIGERATED STORAGE OF FRUITS AND VEGETABLES

The principal refrigeration requirements of fruits and vegetables are controlled low temperature, air circulation and humidity.

Relative humidity (RH): Most food stores are best at refrigeration temperatures when the relative humidity of air is between 80 and 95 per cent. This is generally related to moisture content of foods. Celery, spinach and several other crisp leafy vegetables require 90-95% RH.

Controlled low temperature: Fruits and vegetables are highly perishable because they respire and produce heat at varying rates. They, therefore, need to be stored at low temperatures. Refrigeration is the gentlest method of extending the shelf life of fruits and vegetables. By and large, it has relatively few adverse effects upon taste, texture, nutritive value and overall changes in food, provided simple rules are followed. Domestic refrigerators usually run at 4.4°–7.2°C (40-45°F). Properly designed refrigerators, refrigerated storage rooms and warehouses provide sufficient refrigeration capacity and insulation to maintain the room within about 1°C. Proper insulation is must to maintain the optimum storage temperature. Refrigeration system must be of appropriate size to handle maximum expected heat load as an undersized system will allow temperature to rise during peak heat load conditions. Different fruits and vegetables evolve different heat during respiration. (Table 6.1) As you can see from the table green beans, broccoli, sweet corn, green peas, spinach and strawberry evolve high heat during respiration. These products are difficult to store.

Table 6.1: Heat evolved from respiration of fruits and vegetables

Commodity	Btu per tonne per 24 hrs	
	32°F (0°C)	40°F (4.4°C)
Apples	300-800	590-840
Beans, green	5,500-6,160	9,160-11,390
Broccoli	7,450	11,000-17,600
Carrots	2,130	3,470
Corn (sweet)	6,500	9,390
Onions	600-1,100	1,260-1,980
Oranges	420-1,030	1,300-1,500
Peach	850-1,370	1,440-2,030
Peas	669-880	-
Peas (green)	8,160	13,220
Potatoes	440-880	1,100-1,760
Spinach	4,240-4,860	7,850-11,210
Strawberry	2,730-3,800	3,660-6,750
Tomatoes (ripe)	1,020	1,250

Based on their respiration rate, the storage requirement and shelf-life of fruits and vegetables is also different, e.g., broccoli, a highly respiring vegetable at a storage temperature of 32^{o}F has a shelf-life of 7-10 days in comparison to 6-8 months for onions at same temperature. While temperature is the primary concern in the storage of fruits and vegetables, relative humidity is also important. The relative humidity of the storage unit directly influences water loss in produce. Water loss can severely degrade quality-for instance, wilted greens may require excessive trimming, and grapes may shatter loose from clusters if their stems dry out. Water loss means saleable weight loss and reduced profit.

Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moisture. Humidification devices such as spinning disc aspirators may be used.

Air circulation: Air must be well circulated in the cold storage rooms. This will help more heat away from food surface to cooling coil. Air, that is, circulated within a cold storage must not be too moist or too dry. If it is high in humidity, moisture will condense on surface of cold foods and moulds will grow on these surfaces. On the other hand, if air is too dry, it will cause excessive drying out. Most food stores are best at refrigeration temperatures when the relative humidity of air is between 80-95% for prolonging the storage period. Foods can be protected from losing excessive moisture by using several packaging methods. This forms a barrier for migration of moisture from food to storage temperature.

6.5 CHILLING INJURY OF FRUITS AND VEGETABLES

Low temperature storage may have some deleterious effects also. One such effect is called as chilling injury. Chilling injury has variable symptoms as ripening failure in climacteric fruits, different forms of external or internal discolouration, pre-disposition to microorganism infection, etc. The exact mechanism by which chilling injury affects the crop has still not been determined. It has been shown to be concerned with loss of membrane integrity and ion leakage and changes in enzyme activity.

General symptoms of chilling injury

i) Surface and internal discolouration, e.g., internal browning in apples and brown vascular streaks in banana.

ii) Surface pitting, e.g., in tomato, papaya, mango, limes and lemons.

iii) Development of off-flavour.

iv) Failure to ripen in some climacteric fruits.

v) Incidence of surface mould growth or decay.

The chilling injury depends on storage temperature and varies with crop, e.g., chilling injury symptoms develop in banana around 12.6°C. However, some varieties may be resistant to chilling injury at this temperature. In mango, generally chilling injury occurs at 10-15°C depending upon variety.

Based on sensitivity to chilling injury, the crops are classified as

- Chilling sensitive, and
- Non-chilling sensitive.

Chilling sensitive

Fruits: banana, mango, avocado, papaya, pineapple, citrus, plantains, pomegranate, sapota, guava, olive, etc.

Vegetables: snap beans, cucumber, muskmelon, watermelon, okra, potato, tomato, spinach, sweet potato, summer squash, etc.

Non-chilling sensitive

Fruits: apple, apricot, cherry, fig, peach, pea, plum, strawberry, etc.

Vegetables: asparagus, lima beans, beet root, cabbage, broccoli and carrots.

Mechanism of chilling injury

The general mechanism of chilling injury involves following changes:

i) *Abnormal respiratory response:* This generally involves a sudden upsurge in respiratory rate and respiratory quotient leading to uneven ripening.

ii) *Changes in lipids:* Chilling injury involves irreversible disorganization of cellular membranes like mitochondrial and vacuolar membranes. A phase transition occurs in the cytoplasm and it changes from soil to gel stage. When gel formation occurs, the cytoplasm becomes viscous and its movement is restricted.

iii) *Increased membrane permeability:* This is evident by high percentage of electrolytes leached out of the cell. This further leads to increased rigidity of protoplasm and resistance to flow.

Approaches to control chilling injury in fruits and vegetables

If the tolerance to chilling in the chilling resistant tissues can be increased or if the development of chilling injury symptoms can be delayed, the storage life can be increased. The following approaches are generally recommended to control chilling injury in fruits and vegetables:

i) Temperature conditioning
ii) Intermittent warming
iii) Controlled atmosphere storage
iv) Application of growth regulators
v) Packaging, waxing and other coatings

i) *Temperature conditioning:* A cool temperature conditioning just prior to critical chilling range increases the tolerance of commodities to chilling during subsequent low temperature storage and delays the development of injury symptoms. A cool conditioning at 10°C for 10 days before storing at 4°C in peppers reduces chilling injury symptoms. Sometimes a double step-wise temperature conditioning may be more effective than single step conditions. A hot conditioning may be useful in some cases, e.g., pre-storage heating at 30°C for 17-22 hrs decrease injury.

ii) *Intermittent warming:* Interrupting low temperature storage with one or more short periods of warm temperature increases storage life of some chilling sensitive crops. Intermittent warming treatment must be given before chilling injury becomes irreversible. If applied too late, results are not seen. Intermittent warming is hypothesized to remove toxic or inhibiting substances that accumulate during chilling.

iii) *Controlled atmosphere storage:* Most products respond favourably to decrease in oxygen level and increase in carbon dioxide concentration. Pre-storage treatment of grapefruit with high carbon dioxide is effective during inhibiting pitting during cold storage.

iv) *Application of plant growth regulators:* Application of some plant growth regulators such as ABA, Triazoles and ethylene decreases chilling injury symptoms.

v) *Packaging, waxing and other coatings:* Packaging in plastic films and coatings help to maintain relative humidity and modify gas concentration and prevent chilling injury symptoms.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define chilling injury.

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2. Why should you not store banana in refrigerator?

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3. What are the common symptoms of chilling injury?

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4. List some measures to control chilling injury.

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6.6 EVAPORATIVE COOL STORAGE SYSTEM

On-farm cooling facilities are a valuable asset for any produce operation. A grower who has on farm cooling facility for storing produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge, especially for small-scale producers, is the set-up cost. Refrigerated storage systems are although best but expensive in terms of capital investment. Innovative farmers and researchers have thus created a number of low-cost structures. One such low cost structure is evaporative cool storage which was developed by scientists at Indian Agricultural Research Institute.

Principle

Evaporative cool storage is also called as zero energy cool chamber. It is based on the simple principle of evaporative cooling. Evaporative cooling occurs when air, that is not already saturated with water vapour, is blown across any wet surface. An evaporative cooler consists of a wet porous bed through which air is drawn, cooled and humidified by evaporation of water. The faster the evaporation, the greater is the cooling. Can you now think and tell why it is called a zero energy cool chamber? It is so called because it does not require any electricity or power to operate and all the materials required to make the cool chamber are available easily and cheaply. It can be installed at any site by even unskilled person as it does not require any specialized skill or raw material. This simple storage structure has many advantages. Let's see what are they?

- No mechanical or electrical energy is needed.
- Allows small farmers to store produce for a few days; so growers are not forced to sell at low prices, and incur losses.
- Ideal for use in packing stations and markets.
- Reduces losses and pays for itself in a short time.
- Can also be used for mushroom cultivation, sericulture and storage of bio-fertilizers.
- Raw materials required are re-usable.
- The fruits and vegetables stored do not suffer chilling injury.

Let us find out how to construct a zero-energy cool chamber at farm level. We need simple raw materials like

i) Bricks, riverbed sand, bamboo, khaskhas (or any plant material of similar nature), gunny bags/cloth, etc.

ii) A source of water like a tap, a tubewell, a well, a pond, or a canal. The water can be drawn from the source to the cool chamber with the help of a flexible tube/pipe or any suitable container.

iii) Design and construction*:* The floor of the storage space is made with a single layer of bricks. The side walls are made with a double layer of bricks leaving approximately 3" space between the bricks. The cavity between the bricks is filled with riverbed sand. About 400 bricks are required to make a chamber of the dimensions as given in Fig. 6.3. The top of the storage space is covered with khaskhas /gunny cloth in a bamboo frame structure.

The cool chamber should be constructed under a shed with a lot of aeration. The cool chamber site should be close to the source of water.

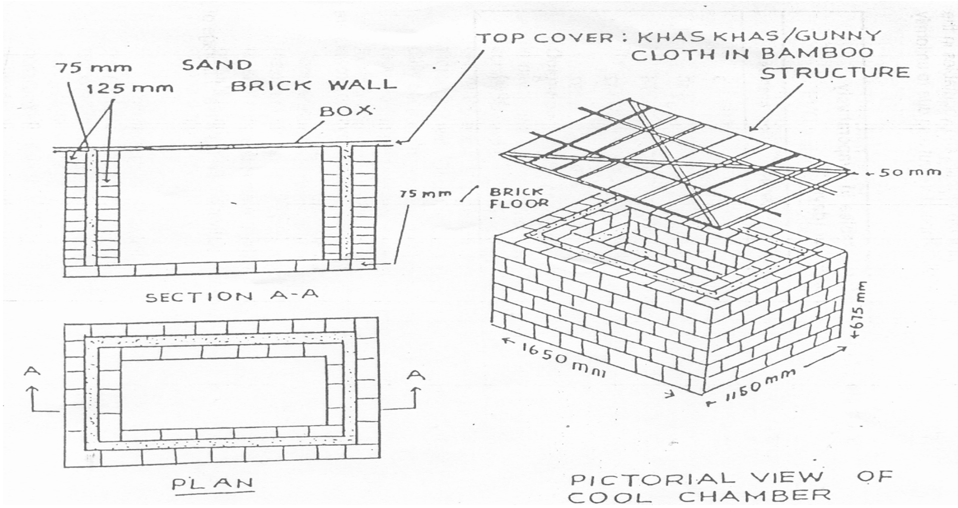

Figure 6.3: Pictorial view of cool chamber

iv) Operation: After construction, bricks of the walls and floor, the sand used in cavity and the top cover made of khaskhas /gunny cloth and bamboo are made completely wet by sprinkling water till they are saturated. It should be ensured before the actual storage of fruits and vegetables that the cool chambers are thoroughly wet. Once the cool chamber is completely wet, sprinkling of water is done once in the morning and once in the evening daily which is enough to maintain the required temperature and humidity. Alternatively, watering can be done by fixing a drip system with a source of water supply. The following precautions are to be observed for smooth functioning of cool chamber:

- Use clean unbroken bricks with good porosity.
- Sand should be clean and free of organic matter and clay.
- Keep the bricks and sand saturated with water.
- Prevent direct exposure to sun.
- Build in an elevated place to avoid water-logging.
- Try to site a place where breezes blow.

Temperature and relative humidity: It has been observed that the average maximum temperature of the cool chamber is considerably low compared to outside temperature throughout the year. During summer, when the maximum outside temperature is 44°C, the maximum cool chamber temperature is never recorded more than 28°C. Similarly, relative humidity of the cool chamber is maintained above 90 per cent practically throughout the year. The minimum relative humidity recorded in the cool chamber is 84 per cent even when the outside humidity is as low as 13 per cent. In general, it is noticed that there is a direct correlation between the outside relative humidity and the temperature difference between the cool chamber and outside. The maximum difference in temperature between cool chamber and outside is noted in the months of April, May and June. This could be attributed to low outside relative humidity during this period. The difference in temperature between the cool chamber and outside could be as high as 18-20°C when the outside humidity is extremely low.

The storage life of fresh fruits and vegetables is considerably increased by keeping them in cool chamber immediately after harvest. Its main advantage is that fruits and vegetables stored in cool chamber do not suffer chilling injury. Increased shelf life of fruits and vegetables in the cool chamber is not only because of low temperature but also due to uniformly high humidity (Table 6.2).

Table 6.2: Shelf life of fruits and vegetables in evaporative cool chamber

Produce	Shelf life (days)		Cool chamber
	Time of storage	Outside	
Leafy vegetables	Summer	< 1	3
Leafy vegetables	Winter	3	8-10
Other vegetables	Summer	1-2	5-6
Other vegetables	Winter	4-5	10-12
Potato	Spring/Summer	40	97
Mango	Summer	4	8
Orange	Winter	8-10	50-60

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the principle of evaporative cooling?

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2. Why is it difficult to store vegetables like peas and broccoli?

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3. What is the optimum humidity requirement for storage of fruits and vegetables?

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6.7 LET US SUM UP

Fresh fruits and vegetables are perishable. They contain high moisture content and liberate heat during respiration. Storage at low temperature removes respiratory heat and extends the shelf life of fruits and vegetables. Refrigeration is best method for low temperature storage but is expensive and energy intensive. Zero-energy cool chamber is a viable option for low temperature storage of farm produce. It is relatively cheaper and can be constructed using locally available materials. During summer when the maximum outside temperature is 44°C, the maximum cool chamber temperature is never recorded more than 28°C. Similarly, relative humidity of the cool chamber is observed above 90 per cent throughout the year. Low temperature storage also has some drawbacks. Some crops are susceptible to chilling injury, a low temperature storage disorder, which manifests in number of ways like abnormal ripening, browning and pitting.

Temperature conditioning, intermittent warming and controlled atmosphere storage are some of the strategies to control chilling injury disorder.

6.8 KEY WORDS

Chilling injury : Chilling injury is a low-temperature physiological disorder or abnormality of crops where freezing is not a factor.

Specific heat : Specific heat of any substance is the heat required to raise or lower the temperature of unit mass of water by 1°C.

Latent heat : Latent heat is the quantity of heat required to change the state or condition under which a substance exists, without changing its temperature, e.g., a definite quantity of heat must be removed from water at 0°C (32°F) to change it to ice at 0°C.

Refrigeration load : It is defined as that quantity of heat which must be removed in order to reduce the temperature of the products from its initial temperature to the temperature consistent with good frozen food storage.

6.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answers should include the following points:

1. Chilling is the low temperature treatment used to extend shelf life of fruits andvegetables. It does not involve ice formation.

2. Phase change in the refrigerator takes place at two places first at the evaporator and second at the condenser.

3. Common refrigerants used in the refrigerator are ammonia, CFC (Chloro fluoro carbon) and freon.

Check Your Progress Exercise 2

Your answers should include the following points:

1. Chilling injury is a low-temperature physiological disorder observed in some crops. The crops develop some abnormalities during freezing.

2. Banana is never stored in refrigerator because it suffers chilling injury at that storage temperature.

3. Surface and internal discoloration, e.g., internal browning in apples and brown vascular streaks in banana. Surface pitting, e.g., in tomato, papaya, mango limes and lemons. Development of off-flavour and failure to ripen in some climacteric fruits.

4.
   - Temperature conditioning
   - Intermittent warming
   - Controlled atmosphere storage
   - Application of growth regulators
   - Packaging , waxing and other coatings

Check Your Progress Exercise 3

Your answer should include the following points

1. When evaporation of water occurs cooling takes place producing cooling effect. The greater the evaporation the greater is the cooling effect.

2. It is difficult to store peas and broccoli because they are high respiring crops and produce large quantities of heat during respiration.

3. Optimum humidity requirement of most fruits and vegetables is 85-95%.

6.10 SOME USEFUL BOOKS

1. Thompson, A.K. (1996) Post harvest technology of fruits and vegetables. Blackwell Science Ltd., London.

2. Verma, L.R. and Joshi, V.K. (2002) Post harvest technology of fruits and vegetables, Vol. 2, Indus Publishing Co., New Delhi.

3. Potter, N. (2002) Food science, CBS Publishers and Distributor, New Delhi.

UNIT 7 CONTROLLED AND MODIFIED ATMOSPHERE STORAGE

Structure

7.0 OBJECTIVES

This unit shall analyze the basic and applied aspects of controlled/ modified atmosphere storage of fruits and vegetables. Here the issues of physiological basis and problems and prospects of CA / MA storage of fruits and vegetables will be discussed. After studying this unit, you will be able to:

- describe the basic requirement of CA/ MA storage;
- explain physiological effects of CA/MA storage on fruits and vegetables;
- enumerate the methods of atmospheric modification; and
- evaluate the economic benefits of CA/ MA technology.

7.1 INTRODUCTION

The effect of gases on harvested fruits is known since ancient times. In earlier days fruits were used to be taken to temples for improved ripening. This was due to the volatiles released on burning of incense containing hydrocarbon gases that helped ripening of the fruits. In 1819 J.E. Bernard in France noticed that harvested fruits absorb O_2 and liberate CO_2.Atmosphere devoid of O_2 caused no ripening in peach, prunes and apricot for several days but ripening continued when they were placed back in air. A commercial cold storage was built in 1856 by B. Nice for apples and ice was used to maintain a temperature of 1°C. After a decade he started experimenting with modifying the cold store gases inside. In 1907 J. Foulton observed the increase in fruit damage by large accumulation of CO_2 in the storage atmosphere. In 1915 R.W. Thatcher after experiments with apples in sealed boxes containing various levels of gases concluded that CO_2 greatly inhibited ripening. The first scientific evidence on the effect of CO_2 on respiratory rates was established by Kidd and West in

1917 in seeds. In the early 1940 the term of 'gas storage' was replaced by Controlled Atmosphere (CA) storage. Now let us discuss the modern understanding of CA/ MA storage.

Atmosphere at ambient conditions comprises of 78.08% N_2, 20.98% O_2 and 0.03% CO_2. Any deviation from this normal atmosphere composition, e.g., elevated level of CO_2 and reduced levels of O_2 and N_2 or any other combination is known as '**Modified Atmosphere**'. When this deviated normal atmosphere is precisely kept under control then it is termed as "**Controlled Atmosphere**". This control can be done in package (Controlled Atmosphere Packaging) or in the storage chamber (CA-storage). Generally, O_2 below 8 per cent and CO_2 above 1 per cent are used in CA-storage. Atmospheric modification is a supplementary practice to temperature management in preserving quality and safety of fresh fruits, vegetables, ornamentals and their products throughout post-harvest handling and storage.

Essentiality of CA/MA technology should be justified only if (a) the commodities are having high market value, (b) it need longer storage life, (c) require significantly better quality, and (d) fetch better price compared to conventional cool stored produce. Retardation of ripening, reduction in decay, prevention of specific disorders and maintenance of product texture are some of the potential advantages of CA/MA storage. However, initiation or aggravation of certain physiological disorders, viz. black heart in potato, brown stain in lettuce, brown heart in apples and pears, etc., take place in CA-storage if appropriate gaseous regimes are not maintained. A concentration of less than 2 per cent O_2 or more than 5 per cent CO_2 in the storage/ package atmosphere results in irregular ripening of banana, tomato and pear. Too low O_2 or too high CO_2 can increase the susceptibility to decay causing organisms. Off-flavour development in fruits and stimulation of sprouting and retardation of periderm formation in potatoes are some of the ill effects of improper CA-condition. On the other hand, a very high concentration of CO_2 (up to 30%) is extremely beneficial in checking the *Botrytis* rot in strawberry fruits.

The quality retention in fresh horticultural produce in CA storage is mainly due to reduction in the respiratory and metabolic activities and check in ethylene liberation.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the basic differences between a controlled atmosphere and modified atmosphere storage?

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2. First scientific evidence on the effect of CO_2 on respiratory rate of fruits was established by _______________.

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3. In general the O_2 concentration below _______ % and CO_2 concentration above _________% are used in CA storage.

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4. What are the essentiality factors to be considered while judging the feasibility of a commodity for CA storage?

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7.2 PHYSIOLOGICAL BASIS OF CONTROLLED ATMOSPHERE (CA) STORAGE

Exposure of fresh horticultural crops to low O_2 and/or elevated CO_2 atmosphere within the range tolerated by each commodity reduce their respiration and ethylene production rates. However, outside this range respiration and ethylene production rates can be stimulated indicating a stress response. This stress can contribute to incidence of physiological disorders and increased susceptibility to decay. Elevated CO_2-induced stresses are additive to and sometimes synergistic with, stresses caused by low O_2; physical or chemical injuries; and exposure to temperatures, RH, and/or ethylene concentrations outside the optimum range for the commodity.

The shift from aerobic to anaerobic respiration depends on fruit maturity and ripeness stage (gas diffusion characteristics), temperature, and duration of exposure to stress-inducing concentrations of O_2 and/or CO_2. Up to a point, fruits and vegetables are able to recover from the detrimental effects of low O_2 and/or high CO_2 stresses (fermentative metabolism) and resume normal respiratory metabolism upon transfer to air. Plant tissues have the capacity for recovery from the stresses caused by brief exposure to fungistatic atmospheres (> 10% CO_2) or insecticidal atmospheres (< 1% O_2 and/or 40 to 80% CO_2). **Climacteric fruits are less tolerant and have lower capacity for recovery following exposure to reduced O_2 and/or elevated CO_2 levels than non-climacteric fruits**. The speed and extent of recovery depend upon duration and levels of stresses, stage of maturity and metabolically driven cellular repair mechanism.

Elevated-CO_2 atmospheres inhibit activity of ACC synthase (key regulatory enzyme of ethylene biosynthesis), while ACC oxidase activity is stimulated at low CO_2 and inhibited at high CO_2 concentrations and/or low O_2 levels. Thus, elevated CO_2 atmospheres inhibit ethylene action. Optimum modified atmospheric compositions retard chlorophyll loss (green colour), biosynthesis of carotenoids (yellow and orange colours) and anthocyanins (red and blue colours), and biosynthesis and oxidation of phenolic compounds (brown colour). Controlled atmospheres slow down the activity of cell wall degrading enzymes involved in softening and enzymes involved in lignification leading to toughening of vegetables. Low O_2 and/or high CO_2 atmospheres influence flavour by reducing loss of acidity, starch to sugar conversion, sugar inter-conversions, and biosynthesis of flavour volatiles. When produce is kept in an optimum atmosphere, retention of ascorbic acid and other vitamins result in retention of better nutritional quality.

Specific responses to CA depend upon cultivar, maturity and ripeness stage, storage temperature and duration, and in some cases, ethylene concentrations. Nitrogen is an inert component of CA. Replacing N_2 with argon or helium may increase diffusivity of O_2, CO_2 and C_2H_4, but they have no direct effect on plant tissues and are more expensive than N_2 as a CA component. Super-atmospheric levels of O_2 up to about 80 per cent may accelerate ethylene-induced degreening of non-climacteric commodities and ripening of climacteric fruits, respiration and ethylene production rates, and incidence of some physiological disorders (such as scald on apples and russet spotting on lettuce). At levels above 80 per cent of O_2 some commodities and post-harvest pathogens suffer from O_2 toxicity. Use of super-atmospheric O_2 levels in CA will likely be limited to situations in which they reduce the negative effects of fungistatic or elevated CO_2 atmospheres on commodities that are sensitive to CO_2-injury.

7.3 EFFECTS OF CA STORAGE

The following are some of the beneficial effects of CA storage.

- Retardation of senescence (including ripening) and associated biochemical and physiological changes, i.e., slowing down rates of respiration, ethylene production, softening, and compositional changes.

- Reduction of sensitivity to ethylene action at O_2 levels < 8% and/or CO_2 levels > 1%.

- Alleviation of certain physiological disorders, such as chilling injury of avocado and some storage disorders, including scald of apples.

- Effects directly or indirectly on post-harvest pathogens (bacteria and fungi) and consequently decay incidence and severity. For example, CO_2 at 10 to 15% significantly inhibit development of *Botrytis* rot on strawberries, cherries, and other perishables.
- Low O_2 (< 1%) and/or elevated CO_2 (40 to 60%) can be a useful tool for insect control during storage of dried products from fruits, vegetables, flowers, nuts and grains.

The harmful effects of CA storage of fruits and vegetables are mentioned below:

- Initiation and/or aggravation of certain physiological disorders, such as internal browning in apples and pears, brown stain of lettuce, and chilling injury of some commodities.
- Irregular ripening of fruits, such as banana, mango, pear, and tomato can result from exposure at O_2 levels below 2% and/or CO_2 levels above 5%.
- Development of off-flavours and off-odours at very low O_2 concentrations and very high CO_2 (as a result of anaerobic respiration and fermentative metabolism)
- Increased susceptibility to decay when the fruit is physiologically injured by too-low O_2 or too-high CO_2 concentrations.

7.4 METHODS OF CREATING MODIFIED ATMOSPHERE CONDITIONS

MAP may be defined as the enclosure of food products in gas-barrier materials in which gaseous environment has been changed in order to inhibit spoilage agents, either by maintaining a higher quality within a perishable food during its natural life or actually extending the shelf life.

Modified atmosphere can be created ***passively*** by the respiration of commodity, also called ***commodity generated*** modified atmosphere, and ***active*** modified atmosphere generation.

7.4.1 Passive Modified Atmosphere

If commodity characteristics are properly matched to film permeability characteristics, an appropriate atmosphere can passively evolve within a sealed package as a result of the consumption of O_2 and the production of CO_2 through respiration. This atmosphere must be established rapidly and without danger of the creation of anoxic conditions on injuriously high level of CO_2.

7.4.2 Active Modified Atmosphere

Because of the limited ability to regulate a passively established atmosphere, an active modified atmosphere can be created by vacuum packaging or replacing the package atmosphere with the desired gas mixture.

- **Vacuum packaging:** It involves placing a product in a film of low O_2 permeability, the removal of air from the package and application of a hermetic seal. During packaging product compression takes place which makes it unsuitable for many products.

- **Gas packaging:** Gas packaging overcomes the limitations of vacuum packaging. Oxygen, nitrogen and carbon dioxide are gases generally used which have specific role, viz. O_2 is essential for respiration of fresh fruits and vegetables, CO_2 is a bacterial and fungal growth inhibitor and nitrogen is inert, tasteless and less prone to pass either into the product or out through the packaging material.

7.4.3 Available Films for MAP

i) Plastic films: The permeability of plastic films is an important attribute which determines their suitability for packaging of fresh fruits and vegetables. An ideal film allows more CO_2 to exit than O_2 to enter. The CO_2 permeability must be somewhere in the range of 3-5 times greater than the oxygen permeability, depending upon the desired atmosphere. Permeability characters of films commonly used for packaging are presented in Table 7.1.

Table 7.1: Gas and water vapour permeabilities of some selected films available for modified atmosphere packaging of fresh produce

Film	Permeability, cc/m^2 day. atm for 25 meq film at 25°C		Water vapour transmission g/m^2 day atm 38°C and 90% RH
	Oxygen	Carbon dioxide	
LDPE	7800	42000	18
HDPE	2600	7600	7-10
Polypropylene cast	3700	1000	10-12
Polypropylene, oriented, OPP	6000-22000	6000-22000	NA
Rigid PVC	150-350	450-1000	30-40
Plasticized PVC	500-30000	1500-46000	15-40
Ethylene vinyl acetate (EVA)	12500	50000	40-60
Microporous, OPP	50000	50000	Variable
	72000	72000	Variable
	120000	120000	Variable
	200000	200000	Variable

NA: Not available

Low density polyethylene (LDPE) and polyvinyl chloride (PVC) are the main films used in packaging of fruits and vegetables. Gas diffusion across a film is determined by: film structure, film permeability to specific gases, thickness, area, concentration gradient across the film, temperature and differences in preserve across the film.

A list of desirable characteristics of plastic films for MAP of fresh produce is as follows:

- Required permeability for the different gases
- Good transparency and gloss

- Light weight
- Heat tear strength and elongation
- Low temperature heat-sealability
- Non toxic
- Non reactant with produce
- Good thermal and ozone resistance
- Good weatherability
- Commercial suitability
- Ease of handling
- Ease of printing for labeling purposes.

ii) **Surface coatings:** These are synthetic and natural chemicals which are composed of lipids, resin, polysaccharides, proteins and composite or bilayer substances. These surface coatings help to maintain quality of fresh produce and to reduce the volume of disposable non-biodegradable packaging materials. They also act by altering the gaseous atmosphere within and surrounding the fruit.

Surface coatings have been developed to overcome the limitations of MAP and CA. The risk of condensation on the inner surface and the associated incidence of rots in plastic films is eliminated. Surface coatings are used to modify internal atmosphere composition thereby delay ripening, reduce water loss and improve the finish of skin.

Requirements for edible films and coatings

- Good sensory qualities
- High carrier and mechanical efficiencies
- Enough biochemical, physiochemical and microbial stability
- Free of toxins and safe for health
- Simple technology
- Non polluting
- Low cost of raw materials and process.

Commonly used coatings

Lipids and Resins – Natural waxes-carnuba wax, candelilla wax, rice bran wax, bees wax, Petroleum based - paraffin, polyethylene wax, mineral oil, vegetable oils (corn, soybean), acetoglycerides, oleic acid, resins (shellac, wood resin, coumarone)

Polysaccharide based – They are very effective barriers to O_2 and CO_2 but not water. Cellulose derivatives: methylecellulose (MC), hydroxy propylcellulose (HPC), and hydroxy propylmethyl celluose (HPMC). These are commercially sold under the name of Nature seal, Tal prolong, Semperfresh. Chitosan based is Nutrisave.

Proteins – Their use in restricted due to high permeability to water.

Composite and bilayer coatings: They are mostly used when both the O_2 and moisture barrier properties need to be incorporated in the surface coating materials. That means the coating should have both hydrophobic and hydrophilic substances. For example, coating materials made up of sodium caseinate.

iii) Relative tolerance of fruits and vegetables to O_2 and CO_2 concentrations

The extent of benefits from CA and MA use depend upon the commodity, cultivar, physiological age (maturity stage), initial quality, concentration of O_2 and CO_2, temperature, and duration of exposure to such conditions. Subjecting a cultivar of a given commodity to O_2 levels below and/or CO_2 levels above its tolerance limits at a specific temperature time combination will result in stress to the living plant tissue, which is manifested as various symptoms. Tables 7.2 and 7.3 include classifications of fruits and vegetables according to their relative tolerance to low O_2 or elevated CO_2 concentrations when kept at or near their optimum storage temperature and relative humidity.

Table 7.2: Classification of fruits and vegetables according to their tolerance to low O_2 concentrations

O_2 concentration (%)	Commodities
1.0	Some cultivars of apples and pears, broccoli, mushroom, garlic, onion
2.0	Most cultivars of apples and pears, kiwifruits, apricot, cherry, nectarine, peach, plum, strawberry, papaya, pineapple, olive, cantaloupe, green bean, celery, lettuce, cabbage, cauliflower, brussels sprouts
3.0	Avocado, persimmon, tomato, pepper, cucumber, artichoke
5.0	Citrus fruits, green pea, asparagus, potato, sweet potato

Table 7.3: Classification of fruits and vegetables according to their tolerance to elevated CO_2 concentrations

CO_2 concentration (%)	Commodities
2	Apples (Golden Delicious), Asian and European pear, apricot, grape, olive, tomato, sweet pepper, lettuce, Chinese cabbage, artichoke, sweet potato
5	Most cultivars of apples and peach, nectarine, plum, orange, avocado, banana, mango, papaya, kiwifruit, pea, chilli, egg plant, cauliflower, cabbage, brussels sprouts, radish, carrot

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark (√) or (X).

   i) The role of CO_2 in CA storage is primarily limited to maintaining the freshness of the produce.

   ii) CO_2 at certain concentration acts as a fungistatic.

   iii) CO_2 at certain concentration acts as a fungicide.

   iv) Excess of CO_2 can cause injury to the produce that is similar to that of mechanical injury.

   v) Reduced level of O_2 results in checking the respiratory rates in CA storage.

2. What are the detrimental effects of CA storage?

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3. Write two different methods of atmospheric modification.

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4. Can we create MA condition by use of surface coating on fruits and vegetables? Mention the different type of surface coatings used in commercial practice abroad.

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7.5 COMMERCIAL APPLICATION OF CA STORAGE

Controlled atmosphere storage systems are used commercially for long-term storage of fresh horticultural crops. Commercial use of CA storage is maximum in apples and pears. Recent researches have shown potential advantages of this method in short-term (a few days) and medium-term (a few weeks) storage of certain types of produce. Optimizing storage conditions requires facilities that allow the temperature and the composition of gases in storage rooms to be controlled precisely. Each product reacts in different way to different concentration of gases.

There are various types of CA systems used in commercial storage. These include generating nitrogen by separation from compressed air using molecular sieve beds or membrane systems. Others are ultra low O_2 (1.0 to 1.5%) storage (ULO), low ethylene (< 1 $\mu L\ L^{-1}$) CA storage; rapid CA storage (rapid establishment of optimal levels of O_2 and CO_2), programmed or sequential CA storage (e.g., storage in 1% O_2 for 2 to 6 weeks followed by storage in 2 to 3% O_2 for the remainder of the storage period), etc. Recent reports of short-term control atmosphere exposure (CAE) techniques indicate a great promise of simulated effect of continuous CA–storage system with particular reference to delay in disease development, delaying the senescence and quality assurance of CA-insensitive climacteric fruits. Other developments include use of atmospheric modification during transport and distribution, improved technologies of establishing, monitoring, and maintaining CA, using edible coatings or polymeric films with appropriate gas permeability to create a desired atmospheric composition around the commodity.

In commercial CA storage the crop is loaded into an insulated store room whose walls have been made gas tight. The temperature is controlled by mechanical refrigeration and the composition of the atmosphere is constantly analysed for carbon dioxide and oxygen levels. Usually the tolerance limits are set at, say plus or minus 0.1%. In active scrubbing, after a predetermined level of CO_2 is reached of the store the atmosphere, is passed through a chemical (CO_2 scrubber) which removes CO_2, and then it is flushed back into the store. In passive scrubbing, the CO_2 scrubber is placed inside the store.

The following factors are to be taken into account with controlled atmosphere storage:

- It is expensive, therefore, only the best fruit should be stored.
- If there is a choice, small fruit should be stored.
- Fruit should be placed in storage as soon as possible after harvest, and in any case within a day.
- The store should be closed and cooled each evening during loading.
- Only one type of crop should be stored in one room and preferably the same cultivar.

The characteristics for a fruit to be compatible with the use of CA are: a long post harvest life, resistance to chilling injury, a large range of non-injurious atmospheres, resistance to fungal and bacterial attack, adaptation to a humid atmosphere, a climacteric fruit that can be ripened during or after storage, and absence of negative CA residual effect.

7.6 ENVIRONMENTAL FACTORS INFLUENCING MA AND CA STORAGES

7.6.1 Temperature and Relative Humidity

The temperature at which a commodity is stored influences the storage life of product, more importantly in film packed commodities. The commodity will cool and warm more slowly than it would if it is exposed directly to ambient temperatures. Temperature also affects the permeability of film. In general, film permeability increases as temperature increases, with CO_2 permeability responding more than O_2 permeability. A film that is appropriate for MAP at one temperature may not be appropriate at other temperature. Relative humidity appears to have little effect on permeability of most films unless actual condensation occurs on the film.

7.6.2 Light

For many commodities, light is not an important factor which influences their post harvest handling. However, green vegetables in the presence of sufficient light, could consume substantial amounts of CO_2 and produce O_2 through photosynthesis. Greening of potatoes can be avoided by using opaque packages.

7.6.3 Sanitation Factors

Packaging of fresh fruits and vegetables in plastic films can create a high-humidity low-oxygen environment that is favourable to pathogenic microorganisms. Care must be taken to avoid conditions favourable to the growth and reproduction of such microorganisms.

7.7 CA SYSTEMS FOR TRANSPORTATION

Many CA systems have been developed for use during transportation. They should be used when transport periods are long and /or fruit is very perishable. Some of the systems in use are:

Oxytral system	Occidental Petroleum Corporation, California, USA	Highway and sea shipment of lettuce, celery, papaya, pineapple
Tectrol system	Transfresh Corporation, California, USA	Lettuce, strawberry, mango, avocado.
CONAIR-Plus System	G+H Montage GmbH, Hamburg, Germany	Apple, avocado, melon, mango.
PRISM CA	Per Mea Inc., St. Louis, Missouri, USA	Apple, pears.
Fresh tainer	Maidstone, England	Apple
NITEC	Spokane, Washington, USA	Apple.

A comprehensive list of most suitable storage atmospheres for CA or MA storage of vegetables is provided in Table 7.4.

Table 7.4: Recommended controlled atmosphere conditions during transport/storage of vegetables

Commodity	Storage temp (°C)	Optimum oxygen (%)	Optimum carbon dioxide (%)	Approximate storage life
Artichoke	0-5	2-3	2-3	29 d
Asparagus	1-5	21	5-10	21 d
Beans. Snap	5-10	8-10	5-10	7-10 d
Beets	8-12	None	None	8 m
Brinjal	0-5	-	-	1-2 wk
Broccoli	0-5	1-2	5-10	2-3 m
Brussels sprouts	0-5	1-2	5-7	2-3 m
Cabbage	0-5	3-5	5-7	6-12 m
Carrot	0-5	None	None	4-5 m
Cauliflower	0-5	2-3	3-4	2-3 m
Celery	0-5	1-4	3-5	1-2 m
Chicory	0-5	3-4	-	2 m
Cucumber	8-12	3-5	0	14-21 d
Leeks	0-5	1-2	3-5	2-3 m
Lettuce	0-5	2-5	0	3-4 wk
Mushrooms	05	air	10-15	3-4 d
Okra	8-12	3-5	0	7-10 d
Onions				
Bulb →	0-5	1-2	0	8 m
Bunching →	0-5	1-2	10-20	2 m
Pea (green)	0-1	5-10	5	5-10 d
Pepper, bell	8-12	3-5	0	2-3 wk
Pepper, chilli	8-12	3-5	0-5%	-
Potatoes	4-12	None	None	-
Pumpkin	7-10	-	-	2-4 m
Radish	0-5	None	None	3-4 wk
Spinach	0-5	air	10-20	2-3 wk
Squashes	7-10	-	-	1-3 m
Tomatoes	5-13	3-5	2-3	2 wks

d=days; wks=weeks; m=months

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which of the following statements are right or wrong? Mark (√) or (X).

   i) Commercially CA storage is meant for long term storage.

   ii) In ultra low oxygen CA storage the O_2 concentration ranges from 1-1.5%.

   iii) The establishment of CA condition is very slow in ULO system of CA storage.

   iv) Mango fruits respond very well to CA storage than apples.

2. Mention three different environmental factors crucial to maintain the efficacy of CA storage.

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3. Mention any three commercial system of MA/CA storage used during transportation.

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7.8 LET US SUM UP

Atmosphere at ambient conditions comprises of 78.08% N_2, 20.98% O_2 and 0.03% CO_2 under normal conditions. Any deviation from this normal atmosphere composition, e.g. elevated level of CO_2, reduced level of O_2, and N_2 or any other combination is known as '**Modified Atmosphere**'. When this deviated normal atmosphere is precisely kept under control then it is termed as "**Controlled Atmosphere**". This control can be done in package (Controlled Atmosphere Packaging) or in the storage chamber (CA-storage). Generally, O_2 below 8% and CO_2 above 1% are used in CA-storage. Atmospheric modification is a supplementary practice to temperature management in preserving quality and safety of fresh fruits, vegetables, ornamentals and their products throughout post-harvest handling. Essentiality of CA/MA technology should be justified only if (a) the commodities are having high market value,

(b) it significantly enhances storage life, (c) it retains significantly better quality, and (d) it fetches better price compared to conventional cool stored produce. Elevated CO_2-induced stresses are additive to and sometimes synergistic with, stresses caused by low O_2; physical or chemical injuries; and exposure to temperatures, RH, and/or ethylene concentrations outside the optimum range for the commodity.

The beneficial effects of controlled atmosphere storage are retardation of senescence, reduction of sensitivity to ethylene action, alleviation of certain physiological disorders and direct or indirect effect on post-harvest pathogens. It can be a useful tool for insect control. The harmful effects of CA storage of fruits and vegetables are initiation and/or aggravation of certain physiological disorders, irregular ripening of fruits, development of off-flavours and off-odours and increased susceptibility to decay.

If commodity characteristics are properly matched to film permeability characteristics, an appropriate atmosphere can passively evolve within a sealed package as a result of the consumption of O_2 and the production of CO_2 through respiration. It is also called passive MA. Because of the limited ability to regulate a passively established atmosphere, an active modified atmosphere can be created by vacuum packaging or replacing the package atmosphere with the desired gas mixture. The permeability of plastic films is an important attribute which determines their suitability for packaging of fresh fruits and vegetables. Surface coatings help to maintain quality of fresh produce and to reduce the volume of disposable non-biodegradable packaging materials. They also act by altering the gaseous atmosphere within and surrounding the fruit and create a MA condition.

There are various types of CA systems used in commercial storage. These include generating nitrogen by separation from compressed air using molecular sieve beds or membrane systems. Others are ultra low O_2 (1.0 to 1.5%) storage (ULO), low ethylene (< 1 $\mu L\ L^{-1}$) CA storage; rapid CA storage (rapid establishment of optimal levels of O_2 and CO_2), and programmed or sequential CA storage (e.g., storage in 1% O_2 for 2 to 6 weeks followed by storage in 2 to 3% O_2 for the remainder of the storage period), etc. Many CA systems have been developed for use during transportation. They should be used when transport periods are long and /or fruit is very perishable.

7.9 KEY WORDS

Modified atmosphere : Atmosphere at ambient conditions comprises of 78.08% N_2, 20.98% O_2 and 0.03% CO_2 under normal conditions. Any deviation from this normal atmosphere composition, e.g. elevated level of CO_2, reduced level of O_2, and N_2 or any other combination is known as **Modified Atmosphere.**

Controlled atmosphere : When this deviated normal atmosphere is precisely kept under control then it is termed as **Controlled Atmosphere**.

Passive modified atmosphere : If commodity characteristics are properly matched to film permeability characteristics an appropriate atmosphere can passively evolve within a sealed package as a result of the consumption of O_2 and the production of CO_2 through respiration

Active modified atmosphere : An active modified atmosphere can be created by vacuum packaging or replacing the package atmosphere with the desired gas mixture.

Vacuum packaging : It involves placing a product in a film of low O_2 permeability, the removal of air from the package and the application of a hermetic seal.

Gas packaging : Gas packaging overcomes the limitations of vacuum packaging. Mixed gases or inert gas is used in the package for specific purposes.

Surface coatings : The synthetic and natural chemicals which are composed of lipids, resin, polysaccharides, proteins and composite or bilayer substances are used as surface coating materials for various purposes. These surface coatings help to maintain quality of fresh produce and to reduce the volume of disposable non-biodegradable packaging materials. Edible films and coatings are also available.

Composite and bilayer coatings : It is mostly used when both the O_2 and moisture barrier properties need to be incorporated in the surface coating materials. This means the coating should have both hydrophobic and hydrophilic substances.

7.10 ANSWERS TO CHECK YOUR PROGRESS EXCERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. Composition of normal atmosphere is 78.08% N_2, 20.98% O_2 and 0.03% CO_2. Any deviation from this normal atmosphere composition i.e., elevated level of CO_2, or reduced levels of O_2, and N_2 or any other combination is known as **Modified Atmosphere**. When this deviated normal atmosphere is precisely kept under control then it is termed as **Controlled Atmosphere**.
2. Kidd and West (1917).
3. O_2 below 8% and CO_2 above 1%.

4. Essentiality of CA/MA technology should be justified only if (a) the commodities are having high market value, (b) need longer storage life, (c) require significantly better quality, and (d) fetch better price compared to conventional cool stored produce.

Check Your Progress Exercise 2

Your answer should include the following points:

1. i) X ii) √ iii) X iv) √ v) √
2. Initiation and/or aggravation of certain physiological disorders, irregular ripening, development of off-flavours and off-odours, and increased susceptibility to decay.
3. Active and passive modification.

Check Your Progress Exercise 3

Your answer should include the following points:

1. i) √ ii) √ iii) X iv) X
2. Temperature and relative humidity, light and sanitation factors.
3. Any three of the following: Oxytral system, Tectrol system, CONAIR-Plus System, PRISM CA, Fresh tainer or NITEC.
4. Yes, Different types of surface coatings materials are:

   i) Lipid and resin based, e.g., carnuba wax
   ii) Polysaccharide based, e.g., Tal prolong
   iii) Protein based, and
   iv) Composite and bilayer coatings

7.11 SOME USEFUL BOOKS

1. Ludford, P.M. and Isenberg, F.M.R. (1987) Brassica crops. In: Weichman, J. (Ed.) Post-harvest physiology of vegetables, Marcel Dekker Inc., New York.
2. Salunkhe, D.K. and Desai, B.B. (1984) Post-harvest biotechnology of vegetables. Vol. I, CRC Press Inc., Florida.
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4. Wills, R.H.H., Lee, T.H., Graham, De., McGlasson, W.B. and Hall, E.G. (1981) Post-harvest: An introduction to the physiology and handling of fruit and vegetables. A VI Publ. Co., Westport, CT.
5. Burton, W.G. (1982) Post-harvest physiology of food crops. Longman, New York.

UNIT 8 FOOD IRRADIATION

Structure

8.0 OBJECTIVES

After studying this unit, you should be able to:

- describe different kinds of ionizing radiations;
- define mechanism of irradiation;
- explain applications of gamma irradiation;
- illustrate the effect of radiation on nutrients;
- describe the effect of radiation on micro organisms; and
- assess the beneficial aspects of food irradiation.

8.1 INTRODUCTION

Food irradiation is a physical process like drying, freezing, canning and pasteurization. Food can be irradiated wet, dry, thawed or frozen. It is a cold process and does not cause change in texture and freshness of food unlike heat. In fact you will not be able to differentiate between irradiated and non-irradiated food on the basis of colour, flavour, taste, aroma or appearance.

This radiation technique is very effective and due to its highly penetrating nature, it can be used on packed food commodities. It means a food commodity, which is packed, can be radiated for sterilization, disinfestation or disinfection purposes and shipped directly.

As you may be aware that many chemical fumigants / preservatives are used to preserve food commodities. Which sometimes leave toxic residues in foods that may be carcinogenic in nature. Contrary to these chemical fumigants, irradiation does not leave any toxic residue in treated foods. So, it is considered very safe. Besides, radiation-processing facilities are environment friendly and safe to workers and public around.

In spite of all its benefits, the radiation processing technique is not a magic wand. It cannot be used to make spoiled or bad food look good. It cannot eliminate already present toxins and pesticides in food. It is a need based technique and can't be applied to all foods. Amenability of a particular food commodity to irradiation needs to be scientifically established and the food commodities that are duly permitted under PFA Act should only be radiation processed.

8.2 IONIZING RADIATIONS

8.2.1 Kinds of Ionizing Radiations

Gamma rays, X-rays and electron beam are the part of invisible light waves of electromagnetic spectrum (U.V. rays are also part of this invisible range but wavelength is not as short as that of X-rays or gamma rays). These high-energy radiations can change atoms into electrically charged ions by knocking out an electron from the outer orbit and thus, are called ionizing radiations. But, at dose levels approved for food irradiation, these radiations cannot penetrate nuclei and thus, food can never become radioactive.

Other types of radiation energy with longer wavelengths are infrared and microwaves. Infrared radiation is used in conventional cooking. Microwaves, due to their relatively longer wavelength, have lower energy levels but are strong enough to move molecules and generate heat through friction.

Three types of ionizing radiations are approved to be used for food irradiation.

i) Electron beams generated from machine sources operate at a maximum energy of 10 MeV.

ii) X-rays generated from machine sources operate at a maximum energy of 5 MeV.

iii) Gamma rays are emitted from Co-60 or Ce-137 with respective energies of 1.33 and 0.67 million electron volts (MeV).

i) Electron beams

Electron beams are streams of very fast moving electrons produced in electron accelerators. For your better understanding, an electron beam generator is comparable to the device at the back of TV tube that propels electrons into the TV screen at the front of the tube. For irradiation using electron beams, only approved electron accelerators can be used. Electron beams have a selective application in food irradiation due to their poor penetration. They can penetrate only one and one half inches deep into the food commodity. As a result, shipping cartons (pre-packed bulk food commodities) are generally too thick to be processed with electron beams. Since electron beams are generated through machine sources, so they can be switched on or off at will and require shielding.

ii) X-rays

X-rays are also generated through machine sources. X-rays are photons and have much better penetration and are able to penetrate through whole cartons of food products. To produce useful quantities of X-rays, a tungsten or tantalum metal plate is attached to the end of accelerator scan horn. The electrons strike the plate and X-rays are generated which pass through the metal plate and penetrate the food product conveyed underneath. But, remember that this X-ray machine is a much powerful version to the machine used in many hospitals and dental clinics. Since X-rays are generated through machine sources, so they can be switched on or off at will and require shielding.

iii) Gamma rays

The third type of ionizing radiations approved for food processing are gamma rays that are produced from radioisotopes either Co-60 or Ce-137. Contrary to electron beams and X-rays, radioisotopes cannot be switched off or on at will and they keep on emitting gamma rays. Radioisotopes require shielding. Co-60 source is kept immersed under water when it is not in use and Ce-137 is shielded in lead. Due to their continuous operation, radioisotopes need to be replenished from time to time. Gamma rays are photons and have deep penetration ability.

8.2.2 Mechanism of Irradiation

The preservative action of ionizing radiations is due to both primary and secondary effects resulting from interaction of radiations with molecules and microorganisms present in food.

i) Primary effect

The incident radiation interacts with the atoms and molecules present in food and cause ejection of electrons. This leads to ionization and dissociation. The ejected electrons cause further excitation of molecules present in food. These are represented in the equation below:

$RH \longrightarrow RH^+ + e^-$ Ionization

$RH \longrightarrow R + H$ Dissociation

$RH \longrightarrow RH^+$ Excitation

ii) Secondary effect (Radiolysis of water)

Since water is present in almost all the foods, either in free or bound form, an understanding of chemical changes which water undergoes is important. Gamma rays excite and ionize water and other molecules along their track, giving rise to excitation, ionization and free radicals. These events contribute a great deal to the secondary effects of gamma radiation.

The summary of happenings can be represented by the equation

$$H_2O \longrightarrow \underbrace{OH^+}_{\text{Free radicals}} + \underbrace{e^-\,aq.}_{\text{Hydrated electron}} + \underbrace{H^+_{FR} + H_2}_{\text{free radicals (FR)}} + H_2O_2 + \underbrace{H_3O^+}_{\text{Hydronium ion}}$$

8.2.3 Process of Gamma Irradiation

In a typical gamma irradiation facility, irradiation is carried out inside an irradiation chamber. The later is shielded by 1.5-1.8 meter thick wall. Radiation source Co-60 is contained in slender pencil like stainless steel casings, which in turn are contained in lead shield. Food products, pre-packed or in bulk are placed in suitable containers and carried into the irradiation chamber with the help of automatic conveyor. The conveyor goes through a concrete wall labyrinth. This concrete wall serves as a shield and prevents radiation from reaching the surrounding area.

For irradiation of food products, the radiation source is raised above the water shield, after activating all safety devices. The food containers or boxes move around the source in the cell and get exposed for a specific length of time that allows them to absorb a defined radiation dose.

Gamma irradiation can be compared to switching on a light, illuminating a room and turning it off. Gamma rays pass into the food, affect the food or target organisms present in food and leave the food. Outcome of irradiation depends on type of food products, radiation dose and organisms present in food.

After radiation, proper handling and processing of food should be ensured, because irradiation cannot prevent further contamination from improper handling or processing. Irradiation cannot be used to make spoiled food good or to clean up 'dirty' food. If food already looks, tastes or smells bad, it cannot be saved by any treatment including irradiation. The bad appearance, taste or smell will remain.

Food processes such as heating, freezing, chemical treatment and irradiation are not intended to serve as substitutes to good hygienic practices. Both at national and international levels, good manufacturing practices govern the handling of specific foods and their products. They must be followed in the preparation of food, whether the food is intended for further processing by irradiation or any other means.

Irradiators are designed with several layers of overlapping protection systems / safety devices to detect any malfunctioning of the equipments and to protect working personnel from accidental exposure to the radiations. Potentially hazardous areas are regularly and meticulously monitored. A system of inter locks / checks prevents unauthorized entry into the radiation chamber when the source is out of shield.

All irradiation facilities are under strict control of regulatory agencies. In India, irradiation facilities operate under direct control of AERB (Atomic Energy Regulatory Board), Bhabha Atomic Research Centre, Mumbai. These facilities are thoroughly evaluated for their efficacy and safety before a license is issued. Further monitoring is through periodic checks and regular inspections of the facility and in case of any non-compliance, severe penalties and delicensing of facility results.

8.2.4 Units of Irradiation

The units used to measure the effects of radiation are gray and sievert in accordance with recommendations of International Organisation for Standardisation (ISO). Formerly, units used for measuring radiation were the rad and the rem.

The gray (Gy) is the unit used to measure absorbed dose of radiation and is equal to one joule of energy absorbed per kg of matter being irradiated. 1 Gy corresponds to 100 rad.

The unit used to measure the dose equivalent to one given exposure, taking into account the different biological effectiveness of different type of radiation, is the sievert (Sv). 1 Sv corresponds to 100 rem.

The unit used to measure the activity of a given source of radiation is Becquerel (Bq). The former unit was Curie (Ci). 1 Bq is equivalent to 2.7 x 10^{-11} Ci.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Mark which of the following statements are right (√) or wrong (X).

   a) 1 Sv is equal to 100 rem ( )

   b) Irradiation can be applied to all types of foods ( )

   c) Irradiation is a cold process ( )

   d) Irradiation can be used to make bad food look good ( )

   e) No radioactivity is induced in the irradiated foods ( )

2. Describe three kinds of ionizing radiations approved for food irradiation.

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3. Explain briefly the primary and secondary effects of irradiation.

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8.3 EFFECT OF IONIZING RADIATION ON NUTRIENTS

All processes cause changes in nutritional value of foods, even storage causes fresh foods to loose nutrients. It is well demonstrated that irradiation up to 10 kGy does not cause any significant change in the nutritional value of macronutrients, i.e., lipids, proteins and carbohydrates.

Vitamins are the most essential micronutrients present in foods. Certain vitamins like A, E, C, K and B_1 are radiation sensitive. They can be reduced by irradiation but they are similarly reduced when treated by other food processing methods. Irradiation may convert Vitamin C (ascorbic acid) to dehydro ascorbic acid, which is another equally usable form of Vitamin C. Fat soluble vitamins like Vitamin D are radiation resistant and survive irradiation of food products.

Minerals are virtually unchanged. Iron is oxidized but the nutrient value of oxidized iron is same as that of unoxidized iron. Other processes like freezing, thawing, storage have similar effects on iron.

So, the bottom line is that irradiation does not have any adverse impact on the nutritional content of a person's diet.

The FAO / IAEA / WHO Joint Expert Committee has concluded that any food commodity irradiated up to an overall dose of 10 kGy is safe and wholesome for human consumption.

8.4 RADIATION SENSITIVITY OF MICROORGANISMS

In case of living organisms, exposure to radiation causes structural and functional changes in macromolecules thereby leading to cell death / injury. DNA or RNA is the most important target for radiation inactivation of living cells. Please note that a low dose that may cause little chemical changes in food can cause sufficient changes in DNA to cause cell death. As you must be aware that DNA carries genetic information and its intactness is important for it's functioning. So, any damage to DNA will result into severe cell injury / death.

Now, radiation acts on DNA in two ways, i.e., i) direct and ii) indirect. In direct action, DNA absorbs radiation and is damaged. The damage to DNA is of various types – single strand breaks, double strand breaks (dsb), alteration of purine or pyrimidine bases or interchain bond formation. In the indirect action, other molecules like water and the free radicals thus produced react with DNA absorb radiation. This primary and secondary effect (direct & indirect effect) we have studied earlier under section 8.2.2.

Both prokaryotic as well as eukaryotic cells possess various DNA repair mechanism, such as direct rejoining of broken ends, excision repair, past replication repair, etc. The double strand breaks are important because most of the microorganisms cannot repair these damages and cells cannot replicate.

When a population of microorganisms is irradiated with a low dose, only a few of the cells are damaged or killed. With increasing dose, the number of survivors decreases exponentially. Different species and different strains of same species require different doses to reach the same degree of inactivation. In order to characterize organisms by their radiation sensitivity, the decimal reduction dose (D_{10}) is used. D_{10} is the dose required to kill 90 per cent of a population.

i) Bacteria

Bacteria are prokaryotic organisms. The cytoplasm is highly hydrated (70-80% water) and is surrounded by cytoplasmic membrane and a cell wall. Chromosomal DNA is not surrounded by a nuclear membrane. Because of high water content and large amount of DNA, bacteria are very sensitive to radiation.

In general, gram –ve bacteria are more sensitive while some gram +ve cocci are extremely resistant due to their highly efficient DNA repair system. Spores are 10-20 times more resistant than vegetative cells because they have little or no free water and are surrounded by thick impermeable wall. Each bacterium is characterized by a particular D_{10} value reflecting its inherent sensitivity to radiation. Certain extrinsic factors like temperature, O_2 content, water activity, nature of medium and presence or absence of sensitizers or protectors also determine the D_{10} value of a particular microorganism.

ii) Virus

Viruses are simplest biological entities. They are metabolically dormant and do not contain cytoplasm or metabolic enzymes needed for growth. They are the obligate intracellular parasites. The simplest virus particle consists, basically, of a nucleic acid genome (DNA or RNA) and a protein coat. The genome size is 100 to 1000 times smaller than that of bacteria. Therefore, viruses are considerably more resistant to radiation than bacteria or fungi. Further, estimation of dose requirements, to ensure safety from viral infections solely through irradiation, ranged from 20 to 100 kGy, which makes irradiation an unlikely choice for virus treatment in foods.

iii) Yeasts and Moulds

Yeats and moulds are eukaryotic cells, i.e., they have a true nucleus. Generally, they are as sensitive to radiation as vegetative cells of bacteria. However, filamentous fungi contain more than one nucleus (may be 100 nucleus per cell) and are highly resistant to radiation.

iv) Prion

The prion particles associated with BSE (Bovine spongiform encephalopathy), commonly known as mad cow disease, do not have nuclei at all. They are not inactivated by irradiation except at extremely high doses. This means irradiation will work very well to eliminate parasites and bacteria from food but will not work to eliminate viruses and prions.

8.5 EFFECT OF IRRADIATION ON INSECTS (QUARANTINE TREATMENT)

Of all the contaminating organisms to which food irradiation is directed, insects are the most complex. The number of insect species probably exceeds a million and around 500 are considered pests of major importance. Pests and their life stages vary in their sensitivity to radiation. The insects that are not immediately killed by radiation are rendered sterile and unable to reproduce. So, irradiation is most accurately called a Pest Control measure. Lethality is not always quarantine application; requirement can be met by using doses that effectively stop reproduction in insects.

Irradiation has marked advantages over chemical fumigants as:

- Irradiation does not leave harmful toxic residues unlike chemical fumigants/pesticides.
- Even at very low dose levels, radiation affects pests at all life stages. Even eggs can be eliminated by radiation unlike chemical fumigants.
- To control pests in stored grains, insecticides / pesticides may need to be applied repeatedly and thus, leading to higher levels of toxic residues. On the contrary, irradiation is one-time effective process.
- As quarantine treatment, irradiation brings two kinds of useful effects:
- Prevention of transfer of insects from one locality to another, as might occur in the shipment of infested foods. Such a transfer could lead to the establishment of the insects in a new area.
- Prevention of insect damage to foods.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why viruses and prions are more radiation resistant than bacteria?

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2. What happens when living organisms are exposed to radiation?

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3. i) Name two vitamins which are radiation sensitive.

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ii) Name two vitamins which are radiation resistant.

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iii) What is D_{10}?

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4. Write True (T) or False (F) for the following statements:

   i) Gram +ve cocci are more radiation resistant in comparison to gram –ve bacteria.

   ii) Single strand breaks of DNA are more important in radiation exposure.

   iii) Protein get adversely affected when foods are irradiated at a dose of 10 kGy.

   iv) Irradiation can even eliminate eggs of pests present in food.

   v) Viruses and prions are easily killed by irradiation.

8.6 PRACTICAL APPLICATIONS OF FOOD IRRADIATION

The recommended doses of ionizing radiation for different purposes in food preservation are different as explained below

a) Low dose, up to 1 kGy

- Sprout inhibition in bulbs and tubers (0.03 – 0.15 kGy).
- Delay in fruit ripening (0.25 – 0.75 kGy).
- Insect dis-infestation and elimination of food-borne parasites (0.25 – 1 kGy).

b) Medium dose, 1 – 10 kGy

- Reduction of spoilage microbes to improve shelf-life of meat, poultry and sea foods under refrigeration (1.5 – 3 kGy).
- Elimination of pathogenic microbes in fresh and frozen meat, poultry & sea foods (3 – 7 kGy).
- Reduction of microbes in spices to improve hygiene (10 kGy).

c) High dose, 25 – 70 kGy

- Elimination of viruses.
- Sterilization of packaged meat, poultry and their products which are shelf stable without refrigeration (25 – 70 kGy).
- Sterilization of hospital diets for immuno compromised patients.
- Food for astronauts in space.

8.7 BENEFICIAL ASPECTS OF FOOD IRRADIATION

8.7.1 Decontamination of Spices

Spices, herbs and vegetable seasonings are valued for their distinctive flavours, colours and aromas. Unfortunately, they are often contaminated with high levels of bacteria, moulds and yeasts. If untreated, the spices will result in rapid spoilage of foods they are supposed to enhance. Since spices are often contaminated with pathogenic bacteria, they can result in serious food-borne illnesses.

Spices are generally decontaminated by irradiation or fumigation with ethylene oxide gas (ETO). To understand the advantages of irradiation over ETO, the various points are given below:

i) Effectiveness

Irradiation is considered the most effective way to sanitize spices and the most countries have allowed it worldwide. Irradiation at a dose between 7.5 – 15 kGy (average dose 10 kGy) has been established to effectively control the microbiological contamination. Storage further enhances the sanitation effect because injured cells are unable to repair and die out over the time.

In comparison, ETO is far less effective. Although, it is a known fact that ETO is highly toxic to microbial contaminants but, it cannot be used alone. To stabilize ETO, it is mixed with 80% CO_2 and steam is used to deliver the gases, which in turn, reduces its microbiological efficacy. Infact, steam increases the moisture level of treated spices and may result in increased mould growth. Moreover, ETO has low penetration than radiation and hence, bulk ground spices cannot be treated effectively using ETO.

Further, to meet the requirements of international standards, spices are generally treated twice or more with ETO and thus, can easily result into unacceptable high levels of toxic chemical residues in treated spices. On the contrary, irradiation is an effective one time process.

ii) Toxic residues

ETO reacts with organic spice components to leave harmful residues, like ethylene chlorohydrin and ethylene bromohydrin, in spices. Ethylene chlorohydrin is a known carcinogen that persists in the spices for many months, even after food processing. For this reason, ETO is banned in many countries. On the contrary, irradiation does not leave any harmful toxic residue and is completely safe.

iii) Loss of sensory attributes

The use of steam with ETO is a strong argument against its use as a spice treatment. Steam results in the loss of volatile oils and hence, loss of aroma and flavour. Treatment with ETO can also result in unacceptable colour change. It results into darkening of onion and garlic powder. Chilies, paprika and turmeric may loose their bright colour. It may cause development of off-flavours in mustard and mustard flour.

On the other hand, radiation treatment preserves all sensory attributes in spices. Chili, paprika and turmeric colours are stable to radiation treatment.

iv) Environment safety issues

Since ETO is a known carcinogen, worker safety issues are the biggest concern in ETO operations. Irradiation has been established as an environment friendly food processing technique.

v) Packaging problems

Most spice packaging materials are compatible with irradiation. Spices packed in bulk packages, retail packages, heat-sealed bags, and gas impervious packs, can be easily and effectively irradiated. Irradiation allows the spice package to remain closed and sealed at all times. On the other hand, in ETO treatment gas impervious packs cannot be used. Further, after treating with ETO, spice packages need to be stored open (for a week or so) gas escape. This causes increased warehousing cost as well as recontamination of spices. In irradiation, there is no waiting period after processing and the material can be shipped directly and thus, no additional storage costs are incurred.

So on the basis of above-mentioned facts, it is concluded that irradiation is the most effective method to sanitize spices, particularly because

- it results in cleaner, better quality spices,
- it does not significantly change the sensory or functional properties of spices,
- it results in much lower levels of microbial contamination and thus, it is an effective treatment to meet international standards of food safety.

A prototype commercial demonstration irradiator with a throughput of 20 tonnes per day for treatment of spices is operational in Vashi, Navi Mumbai. This is under the management of Board of Radiation and Isotope Technology (BRIT), a constituent unit of Deptt. of Atomic Energy (DAE), BARC, Mumbai. A commercial irradiator, Shriram Applied Radiation Centre (SARC), a constituent unit of Shriram Institute for Industrial Research, Delhi is also licensed by AERB to irradiate spices for sanitization.

8.7.2 Delayed Ripening in Fruits

Irradiation at low dose levels (0.25 to 0.75 kGy) can delay ripening and over-ripening in mature but unripe tropical fruits like banana, mango and papaya. Climacteric fruits exhibit delay in ripening only if irradiated in the preclimacteric stage. Once the ripening has been initiated, irradiation does not change or alter the course of ripening.

The self-life of irradiated fruits can further be extended by combing other post harvest procedures like waxing, packaging in perforated bags, refrigeration and modified atmosphere.

8.7.3 Sprout Inhibition in Tubers and Bulbs

Traditionally, onions are bulk stored under ambient conditions in chawls, medas or sheds, the size and design of which varies from region to region. During prolonged storage, losses occur due to sprouting, desiccation and microbial rottage. The estimated losses are 30–50 per cent. Low ambient temperature and high humidity during rainy season promote sprouting. The losses through microbial spoilage can be reduced but sprouting can’t be checked by improving ventilation. Sprouting alone causes 25–30 per cent of total losses. Sprouted onions shrivel faster due to increased water loss by transpiration. The reserve food substances present in the fleshy scales are also used up for the sprout growth, which ultimately renders the onion bulb unfit for consumption.

Some chemical sprout inhibitors such as maleic hydrazide and isopropyl carbamate are used in temperate countries but these are not very effective in sub-tropical and tropical climates. Cold storage at 0-1°C with low relative humidity (65-70%) is also practiced in many temperate countries but strict temperature and humidity control is must. Moreover, cold storage is energy intensive and expensive technique.

On the other hand, irradiation at very low dose levels (0.06-0.09kGy) inhibits sprouting when properly cured bulbs are irradiated within 2-3 weeks of harvesting.

Potatoes cannot be stored more than 4-6 weeks at ambient temperature. They are stored in cold storage at 2-4°C having relative humidity 85-95 per cent. Since the refrigeration facilities in India are not meeting the requirements of increased crop production, so it is feared that 25-30 per cent of the commodity is lost within 2-3 months of harvesting due to dehydration and microbial spoilage.

Irradiation of potatoes combined with refrigeration at 15°C can extend the storage period up to six months with minimum losses. Irradiation has extra benefit over prevailing refrigeration technique.

In general, irradiation at the dose levels required for sprout inhibition of bulbs and tubers does not change their texture, and external appearance, sensory qualities and processing potential.

The first prototype commercial demonstration irradiator for potatoes and onions (POTON) with a throughput of 10 tonnes/hour is being set up in Lasalgaon, Nashik, Maharashtra. This unit is under the management of Board of Radiation & Isotope Technology (BRIT), a constituent unit of Department of Atomic Energy (DAE), BARC, Mumbai. Besides, two pilot plant irradiation facilities, namely the Food Package Irradiator in Food Technology Division, BARC, Mumbai and another at the Defense Laboratory, Jodhpur have been licensed for irradiating food items that have been cleared for domestic trade and consumption.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe two important beneficial applications of food irradiation.

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2. Write True (T) or False (F) for the following statements:

   i) To inhibit sprouting in tubers, a medium dose application is desired.

   ii) Medium dose irradiation can eliminate bacterial pathogens present in food products.

   iii) There is no commercial irradiator in India to process onions and potatoes.

3. Write two advantages of irradiation over ETO in decontamination of spices.

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8.8 LET US SUM UP

- Three types of ionizing radiations are approved for food irradiation.
- Any food commodity irradiated up to 10 kGy is wholesome and safe for human consumption.
- Bacteria, viruses and fungi differ in their sensitivities towards radiation.
- Foods are irradiated at different dose (low, medium and high) levels for different applications.
- Irradiation has benefits over chemical fumigants and other food preservation techniques.
- Irradiation is one time, safe, environment friendly and efficient technique.
- Irradiation can effectively address many issues like food safety, food losses and quarantine treatments. This is a very promising technique in the field of food preservation.
- All irradiated products are labelled with an international logo called 'Radura'. It is also marked with statement "Processed by ionizing radiation" and purpose of Irradiation.

8.9 KEY WORDS

Irradiation : It is the process of preserving the food by ionizing gamma-rays, X-rays and electrons. It destroys the microorganisms and inhibits the biochemical changes.

Gamma-rays : Radioisotopes Co-60 or Ce-137 produce gamma (γ) rays. These rays are photons and have a deep penetration ability.

X-rays : These rays are photons, generated by X-rays machines, operate at an energy level of 5 MeV. They have less penetrative effect them r-rays.

Electron beams : They are fast moving electrons, produced in electron accelerators, operate at a maximum energy level of 10 MeV. They have selective application due to their poor penetration ability.

Mechanism of irradiation : The ionizing radiation preserve the food material by acting in two ways. The primary effect is through ejection of electrically charged or neutral radicals which destroy microorganisms. The secondary effect is ionization of water present in food by radiation. It helps in destruction of microorganism and inhibition of biochemical changes.

8.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. a) √ b) X c) √ d) X e) √

2. The three kinds of ionizing radiations are:

   Gamma rays, X-rays, and Electron beams.

   i) *Gamma rays* – These rays are produced from radio isotopes Co.60 or Ce-137. The gamma rays are photons and have a deep penetration ability. The energies emitted by Co-60 and Ce-137 are 1.33 and 0.67 million electron volts (MeV), respectively.

   ii) *X-rays* – These rays are generated from machine source and operate at an energy level of 5 MeV. These rays are photons and can penetrate through even whole cartons of food.

   iii) *Electron beams* – These are streams of very fast moving electrons produced in electron accelerators and operate at a maximum energy level of 10 MeV. Electron beams have a selective application in food irradiation due to their poor penetration, i.e., only one to one and a half inch deep into the food.

3. The preservative effect of ionizing radiation is due to primary and secondary effects resulting from interaction of radiations with molecules and microorganisms present in food.

The primary effect is due to the ejection of electrons with atoms and molecules present in food. The ejected electrons cause excitation of molecules present in food. The secondary effect of ionization radiation is to excite and ionize water and other molecules, present in food, which in term give rise to excitation, ionization and free radicals.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Since viruses and prions do not contain cytoplasm and metabolic enzymes needed for growth, they are more resistant to irradiation in comparison to bacteria.

2. When living organisms are exposed to radiation structural and functional changes in macromolecules take place which result in cell injury or even death.

3. i) Vitamins A and E.
   ii) Vitamins C and D.
   iii) D_{10} is the irradiation dose required to kill the 90 per cent population of microorganisms present in food.

4. i) T ii) F iii) F iv) T v) F

Check Your Progress Exercise 3

Your answer should include the following points:

1. The two important beneficial applications of irradiation are:

   i) it delays ripening in fruits
   ii) it inhibits sprouting in tubers and bulbs

2. i) F ii) T iii) F

3. The advantages of irradiation are:
   i) It is more effective.
   ii) It does not leave any toxic residues.
   iii) Sensory quality is not affected.
   iv) It is more safe as compared to ETO.
   v) Irradiated food is easy to pack.

8.11 SOME USEFUL BOOKS

1. Food and Drug Administration (HHS) (1997) Irradiation in the Production, Processing and Handling of Food. Final Rule Federal Register, 62, p.64107, & Federal Register 55, p. 18538.

2. Joint FAO/IAEA/WHO study group in High Dose Irradiation (1999) High Dose Irradiation: Wholesomeness of food irradiated with doses above 10 kGy. WHO technical report series 890. World Health Organization, Geneva.

3. Marsden, J.L. (1994) Issue: Irradiation and food safety. American Meat Institute Issues Briefings.

UNIT 9 TYPES OF BY-PRODUCTS

Structure

9.0 OBJECTIVES

After reading this unit, you should be able to:

- list fruit and vegetable handling and marketing wastes;
- characterise the wastes;
- describe by-products from fruit processing waste;
- explain the types of by-products from vegetable processing waste; and
- define the uses of these by-products.

9.1 INTRODUCTION

Fruits and vegetables are integral part of a balance diet as they contain vital nutrients like vitamins, fibre and minerals. Due to the diverse agro-climatic conditions of the country, all kinds of fruits and vegetables are grown. The production of fruits (46 MT) and vegetables (96 MT) has increased at a faster rate in the last decade making the country second largest producer of fruits and vegetables in the world after Brazil and China, respectively. Despite the fact that production of fresh fruits and vegetables is very high, the level of their processing remains at a low ebb, i.e., 2 per cent. In the developed and developing nations like USA, Brazil, Malaysia, Philippines and Israel the level of processing of fruits and vegetables is more than 50 per cent of the total product. So, there is a vast scope of increasing the level of processing in the country. At present there are more than 6000 processing units in the country where installed capacity is around 23 lakh tones. The main fruit and vegetable processed products are juice, concentrate, sauce, slices, jam dehydrated, canned etc. During processing, a huge amount of solid waste is generated, which is some times more than 50 per cent of the produce processed. Apart, waste is also generated at the place of production, handling and marketing and places of consumptions like hotels, restaurants, colleges, essential homes, etc. The effective disposal of waste is waste / by product generated vary from place to place depending upon fruits and vegetables and the way they are utilized. The waste products are in various forms. For instance we have the peel, rag and seeds in case of citrus fruits, peel and stones in mangoes; rings and seeds in jack fruit, core and peel in guavas; seeds, skin and trimmings in tomatoes, etc. Many fruit and vegetable processing plants produce a large amount of by-products. Peel, core, pits, veins, stem, leaves, etc., are the materials discarded by fruit and vegetable processing industries. Their appropriate utilization would not only yield other valuables end-products and lower the cost of production but also minimize pollution problem caused by unhygienic disposal methods.

9.2 HANDLING AND MARKETING WASTES OF FRUITS AND VEGETABLES

The harvested fruits and vegetables are cleaned/ washed/ graded according to size and appearance. These are then packed / bagged or loaded in containers for transportation to markets or retail outlets or to the processing unit. A large number and huge quantity of wastes and by products are generated during handling and marketing of fruits and vegetables. The type and quantity of waste depends upon the crop, the packaging material and the duration / time period of handling the produce. Fruits and vegetables are highly perishable in nature and their quality starts deteriorating the moment they are detached from the plant. Environmental conditions such as ambient temperature, relative humidity, produce storage conditions and, above all, infestation of microbes in the produce, are the main factors responsible for quality degradation during handling and marketing. After identifying the type of available waste it is very important to have a knowledge of general characteristics, such as physical, chemical and microbiological, for deciding their appropriate disposal/ utilization.

Various types of by-products available during fruit and vegetable handling and marketing are:

9.2.1 Fruit Wastes

a) Peel, core, and trimmings
b) Seed/ kernel, stem and pomace
c) Cull fruit
d) Over-ripe and blemished
e) Bruised and diseased

9.2.2 Vegetable Wastes

a) Seed, skin and trimmings
b) Vine and pods
c) Peel and pomace
d) Husk and cobs
e) Over mature and cull
f) Bruised and diseased

9.2.3 Packaging Wastes

Various types and sizes of packaging materials are used for different fruits and vegetables. Waste generated during handling and marketing due to various packagings are as follows:

a) Gunny bags
b) Bamboo crates/"tokras"
c) Wooden boxes

d) Plastic sacks or bags
e) Paddy straw/pine waste/leaves or any other coushing material
f) Foam or thermocole
g) Paper bags or corrugated fibre board boxes

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How many fruit and vegetable processing are industries in the country and what is their installed capacity?

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2. What are the wastes and by products of fruits and vegetables generated during handling and marketing?

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9.3 BY-PRODUCTS FROM FRUIT PROCESSING

The fruit and vegetable processing industry in India is highly decentralized. A large number of units are in the cottage/home scale and small scale sector, having small capacities up to 250 tonnes/annum. But big Indian and multinational companies in the sector have large capacities in the range of 3.0 tonnes per hour or so. In the food processing industries, up to 30 per cent of incoming raw material becomes waste rather than a value-added product. Generally fruit processing wastes are either used as animal feed or as compost.

Specific wastes and by-products from different fruit and vegetable processing industries and their appropriate use are discussed below:

Apple

Apple (*Malus pumila Mill.*) is the most important deciduous fruit. These are mainly grown in the North-Western Indian States of Jammu and Kashmir (J&K), Himachal Pradesh (H.P.) and Uttaranchal hills. The North-Eastern Hills region, comprising of the States of Arunachal Pradesh, Nagaland, Meghalaya, Manipur and Sikkim, also grows some of the deciduous fruits on a limited scale. Major wastes and by-products of apple processing are:

- pomace - obtained after juice extraction
- peel - obtained during canning and murabba preparation
- core and cull fruits

Apple wastes contain pectin varying from 2.5 to 3.4 per cent on fresh weight basis. These wastes can be used for preparation of pectin, cider, vinegar, chutney, etc. Pomace can be dried and utilized for preparation of pectin. Apple pomace being rich source of pectin and a fairly good source of sugars, can be utilized on a small scale for blending with fruits poor in pectin for the preparation of jam, jellies, etc., which require addition of pectin. Apple chutney can be prepared from pomace.

Amla

(Indian goose berry): The amla/aonla (*Emblica officinalis* syn. *Phyllanthus emblica*) is an important minor fruit. Although, it is found growing in different states throughout tropical India, it is more popular in Uttar Pradesh. It is highly nutritive and is one of the richest source of vitamin C. The fruits are made into preserves (*murabba*)**,** pickles, dried chips, candy, toffees, powder, juice, sauce etc. Amla seed is obtained from amla processing industry. The seed can be dried and used in ayurvedic preparations.

Apricot

Apricot (*Prunus armeniaca L.*) is grown in the drier pockets of north-western Himalayas and Leh-Ladakh areas of J&K State. Apricot is a small, soft fruit with white/orange skin. Its kernels are sweet and can be added to jam after removing the seed coat. Generally there are two types of apricot, namely, sweet kernel type and bitter kernel type. Oil can be extracted from kernels and after refining it is just like almond oil and can be used in pharmaceutical and cosmetic preparations. The oil cake is rich in protein and can be used as cattle feed. The kernels are sometimes used for making macaroon paste which is usually made from almonds.

Banana

Banana (*Musa paradisiaca*) is the cheapest, plentiful and most nourshing of all fruits. It is basically a plant of humid tropics and is grown in south, west and east India. All parts of this plant are useful. Various products like banana chip, banana fig, soft drink, flour and powder, jam, etc., can be made. Banana peel and pseudostem are the main waste products from banana processing. The pulpy portion scraped from thick peel of banana can be used for preparation of banana cheese. Pseudostem of banana can be utilized to prepare paper pulp as well as a starch resource for food and feed purposes.

Cashew

Cashew (*Anacardium occidentale*) is an important tropical tree crop. It is mostly grown in malabar coast of India, particularly concentrated in Kerala, Karnataka, Maharashtra, Tamil Nadu and Andhra Pradesh. Every part of cashew is useful to man. The kernels are of high nutritive value, rich in protein, carbohydrate, unsaturated fats, minerals and vitamins. The main by-products are: cashew apple, cashew testa and cashewnut shell liquid. Because of its astringent taste and fibrous texture, only a small quantity of the annual production of cashew apple is consumed locally and a major portion is wasted. About 65 per cent of the juice can be obtained from the apple by extraction. The juice, after removal of astringent and acrid principles, has been found to be suitable for a variety of beverages like clarified juice, cloudy juice and juice blended with other fruit juices. Cashew apples can also be used for the preparation of cashew apple candy, syrup, canned cashew apple, fruit chutney, curried vegetable, pickle, etc. The brown thin skin covering the cashew kernel is called the cashew testa. It is a by-product of the cashew processing industry. Cashew testa is a good source of tannin. At present, this is mostly wasted or occasionally used as a manure in small quantities. However, the disposal of this product is a big problem. Quite often, storage of this husk is found as a ready place for *dryboleum* and so is hazardous in the cashew factories.

The reddish brown viscous liquid inside the two layers of the cashew shell is a versatile industrial raw material known as cashew shell liquid. Its major application is in the manufacture of cashew liquor, cashew cement, laminating resins, rubber compound resins, brake linings, intermediate for chemical industry, epoxy resins, foundry chemicals, composite wood, insulating varnishes, electrical windings, electrical conductors, coating compositions, water and weather proofings, bituminous solutions, specialised protection coatings and compositions based on cardanol.

Citrus

The most important commercial citrus in India is mandarin orange followed by the sweet orange and acid limes. Besides being used as fresh fruits, the citrus fruits are processed into marmalade, juice, concentrate, powder and canned product. The flowers, leaf and rind of citrus contain oils of good fragrance and have good commercial value. Other commercial products are citric acid and pectin, made primarily from cull and unmarketable fruits**.** In case of citrus fruits major waste materials are peel, rags, seeds, and sludge from lime and oranges. The peel can be utilized for getting peel oil, which has a number of uses. The rags can be used for preparation of citrus patty, marmalade and orange toffee. The dried rag can also be used as cattle fed. Orange residues can be fermented into fruit vinegar. Lime juice sludge is used to extract lime oil. Seeds from oranges and lime can be used for extraction of seed oil, which has enormous industrial applications. Juice residues of orange and gulgal can be used to get pectin. Waste from cull, lime, gulgal and khatta can be used to prepare citric acid.

Coconut

Coconut (*Cocos nucifera*) is most beautiful and useful tree of tropics. This crop is of considerable economic importance in the state of Kerala, Tamilnadu, Karnataka and Andhra Pradesh. These have more than 90 per cent of the total production of the crop in the country. There are number of industries which are directly or indirectly dependent on coconut farm. The major wastes and by-products of coconut are stem, leaves, buttons, coconut husk, pit, shell and water. The quire industry utilizes coconut husk and is earning considerable foreign exchange for the country. Quire husk is a waste left over after extraction of fibre from the coconut husk. This light fluffy refuge is a mixture of corcipith, fibre short and apricot. High moisture and saline content are the main problems restricting its utilization. It has been limited agricultural use. It can be used as an accident soil mulchi material. It has certain industrial uses. It can be used for preparation of boards from quire wastes, preparation of installation slabs, air conditioner and refrigeration, manufacturing of moulded articles, expansion joint filler, furfural production, electric plate edited in battery industry and as a tacifying agent in rubber industry. Coconut shell is the endocarp of the coconut fruit. It is available in large quantities near copra making centre or desiccated copra making centre. It can be used as a fuel and manufacturing of fancy articles. Since coconut shells are available in different sizes and shapes, it can be polished and carboned and decorated with lacquer in load with ivory, silver or other metals. A number of fancy articles prepared from coconut shells are lamps, flower, bulb covers, ash tray, paper, tea sets, musical instruments, bangles, etc. Coconut shell flour can be used as a compound film for synthetic season blues, as a fuel for pneumatic moved powder, etc. Furfural can also be extracted from ground coconut shell. Large volumes of coconut water from ripe nuts are run off as waste product by copra manufacturer. The biochemical analysis of coconut water shows negligible amount of sugar. It can be used as a growth media, a rubber coagulant and soft drink. In view of the relatively high potassium content coconut water can be mixed with compost or can be applied directly to coconut palms after mixing with slag lime. Coconut pith can be used for preparing the insulation and as a structural material.

Grape

Major grape (*Vitis vinifera L.*) growing states in India are Maharashtra, Karnatka, Andhra Pradesh and Tamil Nadu. The cultivation of grapes has also started under North Indian conditions. The grapes are used into five different ways, such as, table purpose, canned, juice, wine and raisins. Stem, pomace and seed are main by-products of grape industry. Stem, separated from grapes, normally constitute about 5 per cent of original weight of grapes. The stems can yield cream of tartar (potassium tartrate). The pomace consists of pressed skin and seeds. From the pomace, seeds can be separated and pressed to extract oil, which is edible in refined state. Oil cake can be used to extract tartaric acid. Hulls of decorticated grape seeds can be used to obtain toxin extracts. The pomace can be used for preparation of grape jelly and chutney. It can also be used for preparation of animal feed. Pomace must be dried to less than 10 per cent moisture in order to prevent spoilage by moulding and spontaneous heating. Grape marc can be used for preparation of pectin. Argols (potassium hydrogen tartrate) can be obtained from grape juice settlings.

Guava

Guava (*Psidium guajava L.*) is grown all over the country in tropics and sub tropics. It is a rich source of vitamin C and pectin. It is used for table purpose and for processing to prepare jelly, nectar, juice, cheese, powder and canned guava. Guava peel, seeds, pulp and core are main by-products of guava fruit. These can be utilized to prepare cheese, separately as well as collectively or animal feed. Cheese prepared from peelings only is brown in colour and has satisfactory flavour and good set, whereas cheese from seed is dark brown in colour, sticky and has soft texture and good flavour.

Jack fruit

The Jack fruit (*Artocarpus heterophyllus*) is very popular in eastern and southern parts of the country. The fruit has high nutritive value and is rich source of pectin. It is preserved into pickles, dehydrated, leather, thin *papad* and canned product. Nectar can also be prepared from pulp. The skin and leaves are excellent cattle feed. Seed, thick rind and broken bulbs are the main by-products of jack fruit. Broken bulbs are used to prepare 'leather'. Thick rind with inner perigones can be used for preparation of jelly and pectin. Seeds can be roasted to be used as snack food. Seeds can also be grinded into flour which can be blended with other cereal flours for preparation of products.

Mango

The mango (*Mangifera indica L.*), because of its luscious taste, captivating flavour and great utility, is called the "King of fruits" or "Shahi fruit". It is a major fruit crop grown throughout India. Unripe fruits, because of their acidic taste, are utilized for culinary purpose as well as for preparing pickles, chutney, panna and amchoor. Ripe fruits are utilized in preparing pulp, squash, juice nectar, jam, cereal flakes, dehydrated slices, powder, mango leather (am papar) and toffee. Some mangoes are also sliced and canned for catering to the needs of consumers during off season. The wastes constitute about 50 per cent of the weight of fresh mangoes. Peel and kernel are the wastes from green mangoes as well as ripe mangoes. Pulping machine generates processing wastes. Mango kernel contains about 8.5 per cent crude fibre and 75 per cent N-free extract. Starch obtained from seed kernel can be used to partly replace wheat atta for making chapatees. Oil which forms about 12 per cent of the weight of the kernel is another by-product. Pectin and fibre can be extracted from peel and processing wastes vinegar, citric acid, etc., can be obtained by fermentation of processing waste. The mango waste can also be utilized as animal feed or compost.

Papaya

Papaya (*Carica papaya*) is an important fruit of tropics and subtropics. In India, though it is successfully grown all over the country, the important papaya growing states are Kerala, Tamil Nadu, Assam, Gujarat and Maharashtra. Papaya is a wholesome fruit and ranks second only to mango as a source of precursor of vitamin A. Unripe fruits are commonly used as vegetable for cooking much tenderizer and preparation of tutti-frutti. The ripe fruits are used for table purpose and processed for preparation of jam, soft drink, ice-cream flavouring, crystallized fruits and syrup. Papaya waste a usually peel and trimmings can be used to get proteolytic enzyme papain which has a number of applications in textile, cosmetic and pharmaceutical industries. Pectin can also be recovered from papaya waste.

Passion fruit

Passion fruit (*Passiflora edulis*) is adapted to tropics and subtropic areas with high rainfall. It is a fruit with unique flavour and aroma. Fruit is cut in halves and the pulp scooped out and eaten fresh or added to fruit salad, ice creams or fruit juices. It is processed into fruit nectar, juice, jam, jelly, squash and concentrate. The main wastes of passion fruit are hard rind and seeds. Thick hard rind of this fruit can be used for recovery of pectin, whereas seeds are utilized for extracting oil and pectin.

Peach

Peach (*Prunus persica L. Bats. Ch*) are now being grown commercially in certain areas of the north Indian plains and North-Western States of Jammu and Kashmir, Himachal Pradesh and Uttranchal**.** Peach kernel is the main waste material, which can be used for extraction of kernel oil for industrial uses.

Pear

Pear (*Pyrus communis Berm.f.*) is mainly grown in the North-Western Indian States of Jammu and Kashmir, Himachal Pradesh, Uttranchal and certain areas of the north Indian plains. Peel and core are the main waste by-product obtained from pear and both are used to prepare alcoholic beverage as well as fruit vinegar.

Pineapple

Pineapple (*Ananas comosus)* is most wanted tropical fruit. In India, it is grown mostly in West Bengal, Manipur, Meghalaya, Assam and Tamil Nadu. Pineapple is a good source of vitamins A, B and C and calcium and phosphorus. The processed products from pineapple are slices in cans tit bits, juice, squash, jam and candy. Pineapple wastes constitute 40 to 50 per cent of the fruit weight. Shells, trimmings, peel and pomace are the main waste and by-product of this fruit. Shells and trimmings are utilized to recover pineapple juice mixed with cane sugar syrup for further use in canning of pineapple slices. This juice has also been found useful for preparation of alcohol. The core of pineapple can be used to prepare candies as well as extraction of juice. The press cake from the juice can be used as animal feed. The pomace obtained after extraction of juice from peeled fruit, trimmings and cores can also be used as animal feed. Other products which can be prepared from this waste are alcohol, citric acid, mannosidase, oxalic acid, pineapple gum, flavour and vinegar. Leaves are used for making fine fabric called pina cloth.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the wastes and by products of fruit processing industries?

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2. List by products of coconut processing.

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3. List by products of cashewnut processing.

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4. List by products of mango processing.

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9.4 WASTES AND BY-PRODUCTS FROM VEGETABLES

Tomato

Tomato (*Lycopersicon esculantum*) is an important vegetable crop available round the year. It outranks all other vegetables, except potato crop in popularity and value. It is grown universally in farmer's fields, home gardens and green houses. Peel, seeds and pomace are the wastes obtained during processing of tomato into juice, concentrate, ketchup and sauce. When tomato is canned in lime and sugar solution, some peel and seeds are obtained as wastes. The pomace is either thrown away or used in preparation of compost. Seeds are washed, dried and used for propagation. Edible grade seed oil can also be extracted from seeds. Tomato peel can be utilized for preparation of varnishing and arranging seed oil which compare well with Vit. E and can be used as salad oil and in the manufacture of margarine. The seed meal can be used in fields as fertilizers and also for the preparation of surfactants such as veterinary agents and detergents, etc. The marc constitutes about 12-13 per cent of tomato.

Onion

Onion (*Allium cepa L.*) is one of the most important commercial vegetable crops grown in north as well as in south India. The most important onion growing states are Maharashtra, Tamil Nadu, Andhra Pradesh, Bihar and Punjab. Onions are used as salad and cooked in various ways in all curries, fried, boiled, baked, soup, pickles, etc. The roots are trimmed and the outside skin peeled off leaving the stem clean for further storage/ marketing. Trimmings are obtained as onion wastes. These trimmings are either thrown away or used as compost. The flour component can be extracted from this waste. During handling and grading operations and dehydration loose outer scales are rubbed off. These can also be used as compost.

Potato

Potato (*Solanum tuberosum* L.) is the maximum produced vegetable crop in India. About 80 per cent of the dry matter of potato is starch, which occurs in the form of granules of larger size than those of cereals. Raw potato is generally boiled, cooked, baked or processed into various products such as chips, fingers, cubes, extruded and flour. Potato peel and starch are the waste and by-products obtained during potato processing. Potato peel can be used for preparation of alcoholic beverages as well as compost. Starch is utilized as flour or in cosmetic industry.

Cauliflower

Cauliflower (*Brassica oleracea* L. var. *botrytis*) is an important cole crop. India's production of cauliflower in the world is highest. It is an important winter-session vegetable. It is grown for its white tender head or curd. It is used as vegetable in curries, soups, stuffing in parathas and for pickles. It contains good amount of vitamins and fair amount of protein. Plants are cut below the head and leaves trimmed off. Stalks and trimmings are the main wastes obtained from cauliflower, both in the field as well as in processing industries. These stalks and trimmings can be used as cattle field.

Okra/ Ladyfinger

Ladyfinger (*Abelmoschus esculentus* L.) is a warm season vegetable crop. It is cultivated throughout India for its immature fruits which are generally cooked as vegetable**.** Okra soup and stew are popular dishes**.** Black or brown seeds of ripened okra are roasted and used as a substitute for coffee. The wastes available in the field such as stem of the plant is used for extraction of fibre in paper industry. Stalks are the main by-product in leading processing industry, which can be used as animal feed.

Peas

Pea (*Pisum sativum* L.) is a vegetable crop important from agricultural economy as well as nutrition point of view. Peas are highly nutritive and contain a high percentage of digestible protein along with carbohydrates and vitamins. It is an excellent food taken either as a vegetable or in soup, canned, frozen or dehydrated form. The winnings and rolls are the main waste material from green peas. These wastes can be directly fed to animals or can be dried to make ingredient in animal feed. These wastes are also used as compost.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the wastes and by-products of vegetable processing industries?

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2. List by-products of tomato processing.

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9.5 LET US SUM UP

Fruits and vegetables are valuable parts of a balance diet. The diverse agro-climatic zones of the country make it possible to grow almost all types of fruits and vegetables. Major Indian fruits consist of mango, banana, citrus group, apple, guava, papaya, pineapple and grapes. In case of vegetables, potato, tomato, onion, cabbage and cauliflower account for around 60 per cent of the total vegetable production in the country. Wastes/by-products generated vary from place to place depending upon fruit and vegetable production, marketing sites, processing industries, and major consuming places such as hotels, restaurant, hospitals, schools, colleges and community langars. The fruits and vegetables are processed into various products such as juice, concentrate, canned, dehydrated, jams, jellies, etc. Many fruit and vegetable processing plants produce a large amount of by-products. Peels, cores, pits, veins, stem, leaves, etc., are the materials discarded in processing industries. The waste products are in various forms. For instance peel, rag and seeds in citrus fruits, peel and stones in mangoes; rings and seeds in jack fruit, core and peel in guavas; seeds, skin and trimmings in tomatoes, etc., are obtained. Their appropriate utilization would not only yield other valuables end-products and lower the cost of production but also minimize the pollution problem caused by unhygienic disposal methods. Wastes and by products from important fruits and vegetables such as mango, banana, citrus fruits, apple, guava, papaya, pineapple, grapes, potato, tomato, onion, pea, okra and cauliflower have been discussed. The nutritional quality/characteristic of these by-products varies. Previously, these residues were considered as wastes material to be transported to landfills, burnt, added to soil or fed to cattles. However, these residues are viewed as input materials that can become value-added products with further processing. These wastes are economically utilized for the production of pectin, oil, alcohol, flavours, etc.

9.6 KEY WORDS

By products : Any material or product contingent upon or incidental to a manufacturing process.

Processing waste : Any material generated as waste, in a food processing operation.

Packaging waste : Any material generated as waste from a fruit/ vegetable packaging.

Peel : Outer covering of any fruit or vegetable.

Skin : Outer layer or covering of a fruit or vegetable.

Core : The innermost or centremost part of fruit containing the seeds.

Seed : It is a part of plant capable of developing into another such plant.

Pomace : Waste material obtained during processing of fruits like apple, citrus, etc.

Stem : Stalk of fruit/vegetable or plant.

9.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answers should include the following points:

1. There are more than 6000 fruits and vegetables processing industries where installed capacity is around 23 lakh tonnes.

2. Various types of by-products generated during fruits and vegetables handling & marketing are:

   a) *Fruit wastes:* Peel, core, trimmings, seed/ kernel, stem and pomace, cull fruit, over-ripe and blemished fruits and bruised and diseased

   b) *Vegetable wastes:* Seeds, skin, trimmings, vines, pods, peels, pomace, husk, cobs over mature and cull and bruised and diseased

   c) *Packaging wastes:* Different types and sizes of packaging materials are used for different fruits and vegetables in different areas. Major wastes generated during fruit and vegetable handling and marketing due to various packagings are as follows: Gunny bags, bamboo crates/ "tokras", wooden boxes, plastic sacks or bags, paddy straw/pine waste leaves or any other coushing material, foam, or thermocole and corrugated packing or paper bags.

Check Your Progress Exercise 2

Your answers should include the following points:

1. Peel, core, rags, sludge, pits, pomace, veins, seeds, kernel, shell, rind, stem, leaves, etc., are the materials discarded in fruit processing industries. The waste products are in various forms depending upon the type of fruit being processed. For instance we have the peel, rag and seeds in case of citrus fruits.

2. The major wastes and by-products of coconut are stem, leaves, buttons, coconut husk, pit, shell and water.

3. The main by-products of cashew processing industry are cashew apple, cashew testa and cashewnut shell liquid.

4. The wastes and by-products from mangoes constitute about 50 per cent of the weight of fresh fruits. Peel and kernels are the wastes from green mangoes as well as ripe mangoes. Pulping machine generates mixture of peel and pulp.

Check Your Progress Exercise 3

Your answers should include the following points:

1. Trimmings, peel, core, rags, sludge, veins, seeds, stem, leaves, etc., are the materials discarded in vegetable processing industries.

2. Peel, seeds and pomace are the wastes obtained during processing of tomato.

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UNIT 10 UTILIZATION OF FRUITS AND VEGETABLES PROCESSING WASTES FOR FOOD, FEED, FUEL AND INDUSTRIAL PRODUCTS

Structure

10.0 OBJECTIVES

After reading this unit, you should be able to:

- list various types of fruit and vegetable by-products and processing wastes;
- evaluate quantity of important wastes and their qualitative composition;
- describe the major value added products obtainable from processing wastes;
- transform the fruit and vegetable wastes into value added products for food, feed , fuel and industry;
- develop value added products from fruit and vegetable wastes by fermentation process; and
- define the fruit and vegetable waste water processing techniques and the products developed from waste water.

10.1 INTRODUCTION

You already know that India is one of the largest producer of fruits and vegetables. Fruits are consumed mostly raw and fresh, while the vegetables are usually consumed after cooking. We also know that fruits and vegetables are more prone to spoilage. This spoilage occurs at the time of harvesting, handling, transportation, storage, marketing and processing.

Fruits and vegetables are rich source of vitamins, carbohydrates and minerals and even the inedible portion is rich in nutrients. In most of the countries up to 80 per cent of the total production of fruits and vegetables are processed. However, in India, only around 2 per cent of the total production is processed and that too mostly at cottage and small scale. At present there are more than 4000 processing units with a turn over of more than 8.0 lakh tones of fruit and vegetable products. The processing waste generated by these factories is either gifted away or it is allowed to add to the environmental pollution.

The processing waste can be categorized into solid or liquid wastes. Solid wastes comprise of peels, skins, fragments, pits, spillage, trimmings, cores, fibre and seeds. Liquid wastes include mainly the wash water coming out of factory after processing operations like raw material washing, container washing, blanching, sterilization, cooling and plant and machinery clean up.

We do not have organized method of waste collection and its handling and utilization. Most of the solid waste is dumped or used as landfills. A part of the solid waste is also utilized for cattle feed and manure. Some of the processing units discharge the liquid waste in municipal sewage system. If we do not attend to these wastes, they become a source of pollution and contamination. If we attend to these wastes in scientific manner these can become a rich source of vital constituents like carbohydrates, proteins, fats, minerals, natural colours, pectin, oils, biogas fuel, etc. Efficient disposal and recycling of these by products and wastes will also provide pollution free environment and vital constituents to our foods, feeds and industries. Besides, utilization of waste for by products development will economise the cost of processed products.

In this unit you will learn about various types of fruit and vegetable wastes, their sources of availability and their utilization for food, feed, fuel and industrial raw material.

10.2 FRUITS AND VEGETABLES WASTES

When we process the fruits and vegetables for juices, squashes, jams, jellies, canning and other products, we get large quantities of left over materials. These are called solid wastes. During processing fruits and vegetables produce different kinds of waste material which are described below:

i) Fruit wastes

a) peel, rag, pulp and seeds in citrus
b) peel, stones, and pulper waste in mango
c) rind and seeds in jack fruit
d) peel, core, seeds in guava
e) seeds, and skins in grape
f) pomace of apple
g) apricot kernel, shell and skin
h) peel, core, trimmings, shreds and leaves of pineapple
i) peel, pseudo stem, leaves of banana
j) over ripe and blemished fruits
k) cull fruits and unmarketable surplus

ii) Vegetable wastes

a) tomato seeds, skins and trimmings
b) asparagus wastes from canning
c) vines and pods from pea canning
d) wastes from dryers
e) peel and cores solids of potato

10.3 BY-PRODUCTS FROM FRUIT AND VEGETABLE WASTES

The solid waste obtained from processing of fruits and vegetables is not really a waste but sometimes is an asset. A number of by-products may be obtained from the waste. Some by-products are extracted chemically while others are prepared by using the waste as such (Table 10.1). Here, we will discuss some of the important products prepared / obtained from solid waste.

i) Fat

Mango processing ends up in considerable proportion of peel and stones. On an average stone content in mango is about 15 per cent. India produces around 21 lakh tonnes mango stones or 16 lakh tonnes kernels. The kernel is obtained by decorticating the seed. The estimated fat content in mango kernel is more than 10 per cent. If we can collect and process half of the stones, India can produce about 80,000 tonnes mango fat.

ii) Magaz

Magaz is a seed kernel. You can obtain magaz by decorticating the seeds of cucumber, pumpkin, water melon, musk melon, etc. These have a big market in confectionary, bakery, ice creams and beverages. Apricot kernel is sweet in taste. It looks like almond. It is used in confectionery along with almond. It is also used to improve the appearance of apricot jam. Magaz production can be a good house hold industry.

iii) Starch

Mango kernel obtained after decorticating the seed and banana pseudo stem are good sources of starch. Banana plants provide about 5 per cent edible starch. You will be happy to know that presently more than 1,40,000 tonnes of starch is available from mango seed kernel and 4-5 tonnes starch per thousand banana plants is available.

iv) Tutti-Frutti

The papain extracted papaya and water melon rind after removal of green portion are most suited for the production of tutti-frutti. For this the raw material is needed to cut into small cubes and dipped in sugar syrup. You can give any colour to the syrup of your choice. The tutti-frutti is used in cakes, ice cream, bakery products, etc.

v) Amchur / pickle

Large quantities of dropped green mangoes are available in orchards after dust and thunder-storms. These dropped mangoes may be used for the preparation of pickles, amchur and raw mango slices.

vi) Food grade flavours

Citrus is a good source of flavour. It is a by-product from shaved citrus peel. You can obtain the shaved peel by shaving the spongy albedo layer of the peel and then the flavour is extracted. The flavour life is enhanced by encapsulation so it is adopted to keep the citrus oil-based flavours safe.

vii) Chutney

You can utilize fresh apple pomace, grape pomace, mango and tomato wastes to prepare chutney of various tastes and colours.

viii) Edible oil

You can obtain edible oil from apricot kernel, grape seed and citrus seed. Apricot oil and kernel paste are used like almond oil and paste in cosmetics and pharmaceutical preparations. Grape oil is used to produce grape resins of lustrous appearance. Tomato seed oil is golden in colour. It is used as salad oil.

ix) Cheese and halwa

Guava core, seeds and peel are utilized for the preparation of cheese and halwa. There are certain varieties of banana which have thick peel. The pulpy portion from the thick peel is scraped and used to make cheese.

x) Flour and fortified atta

You can prepare flour of jack fruit seeds, mango kernel and residues left after extracting juice or the unmarketable surplus of fruits like anola and jamun, and vegetables like carrot, radish, spinach, tomato, bitter gourd, etc., by drying and powdering. The flour may be blended with cereal flour. This powder can be mixed with the wheat flour in 1.5 to 3.0 proportions. This flour contains 5.56-11.5 per cent protein, 16.1 per cent fat, 0.35 per cent minerals and 69.2 per cent carbohydrate. You can market it as a health protective flour.

xi) Jam and jelly

You can use apple pomace to make jelly. The thick rind and inner perigones of jack fruit is also used for preparation of high class jelly. White apricot kernel is added to apricot jam to make it more attractive.

xii) Marmalade

You know that marmalade is prepared from citrus peel. The process involves washing of fruit peel, slicing or comminuting the peel, boiling to tenderize and remove bitterness, cooking with sugar or fruit syrup, and adding pectin.

xiii) Candied peel

You can prepare candied peel from orange or grape fruit peel. The primary use is in baking, where candied peel is a condiment used for flavour, appearance, and texture in products like fruitcakes. The peels are cooked to tenderize, remove bitterness and undesirable flavours, drain and dice. The diced peel is equilibrated and cooked in sugar syrup and food dyes are added. The final product is drained, air dried and packaged in polyethylene containers after coating with fine dust of corn starch.

xiv) Citrus purées and bases

You can utilize citrus pulp and unconsumed fruits to manufacture purees and bases. Preparation generally involves grinding, pasteurizing, addition of pectinase to reduce viscosity, comminuting to make a paste of smooth puree, followed by sieving to remove broken seed hulls and non-disintegrated particles. Different preparations are used for different product base purees.

Table 10.1: Possible by-products from solid wastes in fruit processing units

Fruit / vegetable	Waste (%)	Nature of waste	By-products
Apple	20-30	*Pomace*	Juice, wine, vinegar, pectin cattle feed
Citrus Orange	50	Peel, seeds, pulp	Essential oil, pectin, cattle feed, peel candy, pulp wash etc
Lime	60	Peel, seeds, pulp	Essential oil, pectin, cattle feed, peel candy, etc
Mango	40-60	Peel, Stones, Pulper waste	Pectin, cattle feed, alcohol, fat, starch, tannins, vinegar
Mango peels	12-15	Peel and pulp	Pectin, alcohol, cattle feed
Mango pulper waste	5-10	Fibre	Wine, vinegar, juice
Mango Kernels	15-20	Hull & Kernel	fat, tannins, starch
Pine-apple	30-60	Peel, leaves, core, trimmings, shreads	Brome line, cattle feed, biogas, fiber
Tomato	20-30	Core, peels and seeds	Cattle feed, seed oil and meal
Potato	10-11	Peel and coarse solid	Cattle feed, single cell protein
Banana	20-30	Peel	Poultry and cattle feed
Banana	20-25	Pseudo stem	5% starch
Banana dry leave	20-25 /plant	Dry leave	Cups and Trays
Banana	20-25/plant	Green leave	To serve meals

10.4 INDUSTRIAL PRODUCTS FROM FRUIT AND VEGETABLE WASTES

Apart from utilizing the solid waste for preparation of some products as discussed above, it could also be used for the preparation of some industrial products. Some of these products are described below:

i) Industrial oil

Cashew shell contains about 20 per cent oil and resin. You can use this oil for insulation of electric wiring, break lining and preparing foundry moulds and cores. In many countries cashew shell is finding better place than the cashew nuts. Other sources of sweet and bitter oil are the waste of wild apricots (*chulli*), peach kernels, citrus seed and tomato seed. These oils are used in cosmetics and pharmaceutical, and after refining in food items.

ii) Pectin

Pectin is a by-product of mango and citrus peel, apple pomace, raw papaya, cashew apple, etc. Pectin is used for making jam, pharmaceutical preparations and industrial uses.

iii) Essential oil

Do you know that citrus wastes are a rich source of essential oil? You can extract peel oil in small- scale unit. For such unit you can get fresh peel from fresh-juice vending stands. There are two systems of oil extraction. One, cold pressing and second steam distillation. You can choose any one of these. The current production potential of essential oil is more than 15,000 tonnes per annum.

iv) Natural colour

You know that coaltar dyes have carcinogenic effects. Therefore, it is better to replace them as rapidly as possible the herbal or natural colours. Industries are now extracting colours from blue grape skins, kokum (*Garcinia indica*), phalsa (*Grewia subinaequalis*), jamun, safflower, etc. Methods are also available to produce colour concentrates and powders.

v) Cups and plates

A banana plant contains 20-25 green leaves. Farmers harvest banana along with the plant. The green and dried leaves are used to prepare disposable cups and plates to serve meals.

vi) Other industrial uses

Beside the products described above, there are numerous other items which can be prepared from the fruit and vegetable wastes. The few important ones are:

- Citric acid from lemon peel
- Varnish and resin from tomato peel
- Surfactantants, wetting agents and detergents from tomato seed meal
- Citrus seed and mango kernel oils for soaps and detergents
- Glucosides and bioflavins anti-oxidants from citrus peel
- Papaya latex for proteolytic enzyme papain
- Paper pulp from banana stem
- Fibre from pineapple leaves, mango peel and apple pomace

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the principal fruit and vegetable wastes?

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2. Name the important value added food products, which you can produce from the wastes of fruits and vegetables.

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3. What are the industrial products manufactured from fruit and vegetable wastes?

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4. Give one major source for the following products:

   Fat --- ; Starch ---; Magaz --- ; Natural colour ---; Essential oil ---; Amchur ---; Cheese ---; Health Flour ---%.

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10.5 ANIMAL FEED FROM WASTES

We know that wastes and by-products obtainable from fruits and vegetables are a good source of cattle and poultry feed. Let us know how to utilize the major wastes for feed.

i) Citrus wet peel

Citrus peel contains 6% protein, 5% fat, 12% crude fibre, 7% ash and about 60% nitrogen-free extract. Wet peel contains 70-90% moisture. Wet peel or fresh peel is consumed by the animals directly. This practice is feasible only in the close vicinity of peel availability. Life of wet peel is very short due to rapid decay and sap leakage through transport trailer. It is transportable to only short distances. You can overcome this problem by pressing the wet peel where about 10% moisture is removed. This is called press liquor. Before pressing, you must treat the peel by lime. Storability and transportability of lime treated pressed peel is more as compared to wet peel.

ii) Citrus dried peel

Dried citrus peel is the most common form of animal feed. Before drying, peel is shreded and treated with 0.2 per cent lime. The lime aids in breaking down the pectin and in turn releasing the pectin-bond moisture. The peel is then pressed to remove the moisture. The peel is dried mechanically or in the sun. Process the dry peel into pellets or powder bran. You can use citric molasses as a binding agent. Pellets are easy to feed, easy to store and easy to handle and transport.

iii) Skin, core, trimmings, shreds and leaves

Skin, core, trimmings, seeds, shreds, leaves and pomace make a good cattle feed. One can feed them directly to the animals or dry for future use in various forms. You can also ensile them with rice/wheat straw or with stovers of millets and maize in 1:10 proportion with 1 per cent molasses and 0.2 per cent urea.

iv) Wet pineapple bran

The pineapple skin and ends are the major source of pineapple bran. The process involves maceration of the material and pressing. The pressed material is called wet pineapple bran. In this state it is easier to handle and store for short duration.

v) Dry pineapple bran

It is dried form of wet bran. The dried stuff is easy to handle, store and transport. The citrus peel, pomace of different fruits, residues of vegetables and pineapple bran can be dried in sun, polyhouse or rotary drier. The pineapple press liquor has about the same composition as pineapple juice. It can be concentrated and mixed with bran. You can sell such bran in market as concentrate feed for animal.

vi) Poultry feed

You can prepare quality poultry feed from banana peel, mango seed kernel, dried mango peel and citrus and tomato seeds. The dried peel is milled and used as poultry feed. Citrus seed meal contains 32.5 per cent protein, 7.5 per cent fat and 8.0% crude fibre. Tomato seed meal contains 37 per cent protein. It is energy food for poultry feed. Similarly, apricot kernel oil cake is also rich in protein.

vii) Tomato waste

Tomato waste is available in the form of peel, seed and pomace. After extracting varnish from peel and oil from seed, you get marc or solids. This amounts to 12.4% of fresh tomatoes. The marc contains 8-10 per cent protein and 10-12 per cent fat. Therefore, it is a good source of cattle feed.

viii) Molasses

The extract of mango and citrus waste such as peel, peel juice, pomace and trimmings is raw material to produce feed grade molasses. You can either feed it to the animals in liquid form or convert it into molasses. The waste is collected and lime is added to raise the pH. A reaction time of about 18 minutes is given in the mixing tank. The mixture is pressed and the press liquor is collected in a tank. The residue left after extraction of press liquor is dried. The press liquor is concentrated into molasses by evaporating the liquor to a brix value of 72.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List the important fruit and vegetable wastes used for manufacture of cattle feed.

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2. List the fruit and vegetable wastes used for poultry feed.

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3. What is pineapple bran? Describe the technique of preparing wet and dry pineapple bran.

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4. What is molasses? What are the raw materials for molasses?

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10.6 PULP WASH, RECOVERY AND UTILIZATION

i) Pulp washing process

During the process of juice extraction you get pulp and pulpy juice as by-products. Scientifically they are called Water Extracted Soluble Fruit Solids (WESFS) or Washed Pulp Solids. For efficient extraction, you can use four-staged countercurrent pulp washing system. Each stage has screw type mixing device. The pulp put into the process at stage-1 exits at stage –4 as spent pulp. Pure water enters at stage-4 and exits at stage-1 as the pulp wash or strong liquor. The average Brix value of orange pulp wash are in the range of 4-7°Brix. The spent pulp goes for feed. The pulp wash is either concentrated or combined with juice which goes for concentration.

Towards the end of fruit season, soluble pectin in the pulp wash increases. This happens especially in grape fruits. The soluble pectin increases viscosity of the strong liquor which retards the concentration process of strong liquor. You can use pectinolytic enzymes to overcome this problem. This enzyme facilitates in viscosity reduction. Manufacturers of juice, beverages and drink products use pulp wash concentrate. This adds fruit solids and natural cloudiness to juice and beverages. This is also cheaper than juice concentrate.

ii) Juice pulp recovery

During juice recovery, the juice contains part of ruptured juice vesicles or floating pulp. This pulp is recovered as a by-product. The juice first goes to a paddle finisher to remove seeds and rag. Then the pulpy juice passes to a conical cyclone separator, called hydrocylone, to remove the embryonic seeds and other defects. The pulpy juice comes out at the top of the hydrocyclone and goes to pasteurizer and again to finisher (screen) for separation of pulp and juice.

This pulp is used for blending in juice concentrates. It adds texture, body and pulpy character to the reconstituted juices or drinks.

iii) Whole juice sacks or edible tissue

The dried juice sack is a by-product of juice from grape fruits and lemons. It has application in number of food products. It is a functional food ingredient. It imparts textural properties. It increases the water binding and retention property of products. The dried juice sacs hydrate readily. It can mute flavour in some food products. The potential uses are: to provide pulp for dry beverages mixes, to provide thickening or gelling in jams, sauces, fibre breads, cake, cookies and cereals.

To separate out the sacks, you need to peel and sectionize the fruit. Now carry out vigorous agitating and rinsing. The sacks start floating in the mixture which recovered by passing the mixture over a vibrating screen. Now dry the sacks carefully in the poly house or mechanical drier.

iv) Peel fiber

Considerable interest has been generated recently in using the fibre in human diet. It is a by-product left after pectin recovery from peel of many fruits like citrus, apple, mango, etc. The pectin free dried peel contains about 60 per cent dietary fibre. This fibre ranks with cereal bran in importance. The manufacturing process involves chopping the residue into small pieces, reacting with calcium hydroxide, pressing to remove soluble sugars and water, blending with sesame flour, dehydration to 8 per cent moisture, and milling to an acceptable small particle size.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are pulp wash and pulp wash solids?

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2. What is juice pulp and how is it used?

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3. What are juice sacks? How can you utilize these sacks?

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10.7 FERMENTATIVE UTILIZATION OF FRUIT AND VEGETABLE WASTE

It is already clear to us that wastes from fruits and vegetables processing industries are valuable natural resources for many products. They have enormous economic potential. We can make a number of value-added products from these wastes. Principally the waste include water and organic substances. The organic substances are simple and complex polysaccharides (sugars, starch, pectin, etc.), vitamins and minerals. Utilization of the wastewater has been discussed under Unit 10.8. Here we will deal with the conversion of organic substances into value-added products through microbial fermentation technology.

The value added products obtainable from fruit and vegetable wastes are:

i) Fermented edible products
ii) Single cell protein
iii) Animal feed
iv) Ethanol
v) Enzyme
vi) Food additives
vii) Organic compounds
viii) Biogas

i) Fermentable edible products

You can prepare a number of beverages such as cider, beer, wine and brandy, and vinegar by fermentation of fruit wastes.

Cider: Dried, culled, undersized, substandard and unmarketable surplus of apples, grapes, oranges, pineapple and their by-products such as pomace are suitable for cider making. Cider is obtained by combining the distillates from fermented pomace with fermented juice. It contains 1 to 8 per cent alcohol, 4 per cent acetic acid, 5 ppm Cu, 10 ppm Fe, and 1 ppm Pb.

Vinegar: You can use mango peel and stones to prepare mango vinegar. We know that fermentable sugars adhere to the fruit processing waste. It is an ideal substrate for fermentation. The alcoholic level in this fermentation remains between 2.5 to 3.5 per cent. This quantity is not sufficient for alcoholic fermentation. Therefore, you need to raise this level by conducting secondary fermentation or by adding cane sugar. The batch type process takes 3-12 days for completion. You can produce mango vinegar by recycling of *Saccharomyces cerevisiae* and immobilized *Acetobacter aceti.* The good quality vinegar will have 5.3 per cent acetic acid, light yellow colour and pleasant flavour. Similarly, we can prepare vinegar from the substandard and unmarketable fruits of plum, pineapple, banana, etc.

ii) Single cell proteins (SCP)

SCP is a non-conventional source of protein. Microbial growth and microbial biomass are the basis for SCP. A number of organisms like yeast, fungi, algae and bacteria are employed for the production of SCP on different kind of substrates (Table 10.2). You can use SCP as protein supplement for food and feed.

Table 10.2: Different substrates and microorganisms to produce SCP

Name of substrate	Microorganism used	Effect on protein content or BOD
Pectin extracted apple pomace	*Trichoderma viride,* *Aspergillus niger* *Candida utilis*	35% content protein
Grape waste and pressed apple pulp	*Aspergillus niger*	35% content protein
Pineapple waste and citrus peel	*Fusarium*	35% content protein
Cassava waste	*Aspergillus niger* *Endomycopsis fibuliger* *Candida utilis* *Aspergillus tomari*	20-22.5% content protein
Molasses	*Saccharomyces cerevisiae* *Torulopsis utilis*	40-47% content protein
Potato peels and wastes from grape and orange	*Pliorotus astreatus* *S. fibuliger* *C. utilis*	31.6% content protein
Sweet potato waste	*fungi imperfecti*	31.6% content protein

The different wastes support the growth of different microorganisms. The microorganisms use these substances as starting materials for fermentation and SCP production by assimilation.

iii) Animal feed

The wastes obtained from processing of fruits and vegetables are rich in fibre but poor in protein content. Owing to their low protein content and low digestibility, these are poor sources of animal feed. You can increase the feed value of these waste materials through substrate fermentation technique. The various substrates and microorganisms employed for preparation of animal feed are given in the Table 10.2.

iv) Ethanol

You can produce ethanol from wastes of fruit and vegetable processing industries. These wastes are rich in cellulose, hemi cellulose and lignins. Solid-state fermentation (SSF) technique is useful to produce ethanol. The ethanol has several uses such as liquid fuel or liquid fuel supplement or solvent for many industries. Apple pomace, cherry wastes, citrus wastes, etc., can produce ethanol by employing *Saccharomyces cerevisiae, Candia utilis* and *Torula* for apple pomace, *S. cerevisiae* for citrus waste, and *E. coli* and *Klebsiella oxyloca* for lignocellulosic wastes.

v) Enzyme

Submerged fermentation (SF) and solid-state fermentation (SSF) techniques are useful for enzyme production. Food production industries have wider application of various enzymes. Different enzymes can be produced by fermenting different wastes of fruits and vegetables. For this you need different types of microorganisms. To produce cellulase and xylanase enzymes from apple pomace you need *T. viridae and Aspergillus spp* as microorganisms. Similarly to produce cellulase, xylanase and ligninase from grape wine waste you need *Cerrena unicolor*.

vi) Food additives

Brewery wastes, apple pomace, pineapple residues, molasses, sweet potato residue, mandarine orange wastes, grape pomace, etc., are potential sources for citric acid production. Industries utilize solid-state fermentation (SSF) technique to produce citric acid on commercial scale. They use microorganisms *Aspergillus niger* for SSF.

You can also produce pectin by growing microorganisms on wastes. *Trichosporon penicilliatum* is the most common microorganism grown over citrus peel for production of pectin. This pectin has high level of neutral sugar and molecular weight.

The use of colours to the food is an ancient practice. Earlier people used natural colours. But now, people turned to the coal tar dyes. These synthetic colours adversely effect our health. On the other hand, the microbial colours have anti- neoplastic activity. Therefore, encouragement is being given to produce microbial colours from the wastes of fruits and vegetables. Microorganisms like *Rhodotorula*, *Cruptococcus*, *Phoffia rhodozyma*, *Monoascus purpureus* and *Bacillus spp* are known to produce pigments through fermentation techniques.

Wastes available from fruits and vegetables are the cheapest renewable sources to produce flavours and gums. Microorganisms can produce specific flavours and aromas like fruity, spicy, *pyrazines*, *terpenes*, *lactones* and esters. Microbial enzymes like *lipase* are used to generate flavours. Similarly, microorganisms can also produce microbial gums like xanthan. *Xanthamonas compestris* are employed to produce xanthan from cabbage and citrus wastes.

vii) Organic compounds

The organic compounds like butamol, acetone, citric acid, lactic acid and acetic acid are produced through microbial fermentation of wastes molasses. 2, 3-butylenes glycol can be produced by fermenting citrus peel juice and citrus waste after adding molasses.

viii) Biogas

Biogas is an important by-product prepared from numerous agricultural wastes. Fruit and vegetable processing waste is rich in biodegradable substances and can be used for the production of biogas. It is produced by anaerobic digestion of the waste. Methanotropic bacteria like *Methanobacterium* and *Methanococus* spp have the ability to utilize CO_2 from these wastes to produce methane – a biogas. Sometimes, pretreatment of the wastes is useful for higher methane production.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the important value added products you can obtain through microbial fermentation of fruit and vegetable wastes?

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2. Describe briefly the process to produce vinegar.

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3. What is single cell protein (SCP)? To what extent SCP can increase the protein content? List 7 microorganisms used to produce SCP.

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4. What is microbial pigment?

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10.8 FRUIT AND VEGETABLES PROCESSING WASTEWATER TREATMENT AND UTILIZATION

You know that the fruit and vegetable processing industries generate a lot of waste water containing organic material. This waste has high Biological

Oxygen Demand (BOD). BOD is the measured amount of oxygen required by acclimated micro-organism to biologically degrade the organic matter in the waste water to CO_2 and H_2O in a closed system. Oxygen consumed or BOD is proportional to the organic matter converted. If you discharge this waste in the natural water stream without treatment, it will deplete the dissolved oxygen. As a result of this the fish and other biological life in water will parish. The stream water will also become unfit for any domestic use.

The major characteristics of wastewater are pH, total suspended solids (TSS), BOD, oil and grease and nutrients (nitrogen and phosphorous) available for bacterial growth. The quantitative characteristics of some selected fruit and vegetable processing industries are given in the Tables 10.3 and 10.4 below.

Table 10.3: Wastewater characteristics from some selected fruit and vegetable processing industries

Fruit/Vegetable processed	Wastewater (kg / tonne of raw product)	BOD (kg / tonne of raw product)	TSS (kg / tonne of raw product)
Apple	10	09.0	02.2
Apricots	23	20.0	04.9
Dry beans	37	30.0	21.0
Beets	11	26.5	11.0
Carrot	14	15.0	03.5
Cauliflower	71	8.0	03.0
Mushrooms	33	7.0	03.6
Olives	34	13.5	13.0
Peaches	13	17.5	04.3
Pears	15	25.0	-
Plums	10	05.0	01.0
Pickles	15	21.0	04.1
Potatoes/Sweet potato	09	46.5	28.1
Pumpkin	01.2	16.0	38.1

Table 10.4: Wastewater characteristics of some fruit juices

Type of juice production	pH range	BOD range (g/L)	COD range (g/L)
Apple	3.2-3.4	61.5-94.5	85.0-155.0
Orange	3.6-3.8	60.9-5.0	83.4-134.6
Pear	3.2-3.6	88.0-109.2	72.8-175.3
Apricot	3.5	105	194.0
Peach	3.2	100	174.2
Mixed	3.2	65	95.5
Banana	4.1	110	184.1
Grape, white	3.2	80.0-89.0	116.8
Grape, red	2.9	78.0-99.0	115.6

Vegetable	3.8	20.0	050.0

The wastewater from fruit and vegetable industry is not really a waste. It is a useful by-product or a resource material. You can recover the following useful materials from the wastewater as by-product.

- pectin from apple waste
- essences from citrus peels
- alcohol by solid state fermentation
- feed from pomace
- soup and chutney from mushroom wastes
- single cell protein from potato wastes

I. By-product recovery and treatments

The waste water contains oil and grease, suspended solids and organic load. The following steps are involved in recovery of the by-products from waste water.

a) *Screening or removal of solids*

You can remove the floating and suspended matter by passing the wastewater through 20-40 mesh stationery screen or vibrating gyro screens.

b) *Oil and grease removal*

Remove the oil and grease present in wastewater using the principle of density variation in water and oil. You can construct skimming tanks with baffle walls of 24 to 30 min retention capacity for this purpose.

c) *Primary clarification*

Primary clarification is also termed as primary settling. It separates the solids from liquid. The solid particles settle on bottom of tank under gravity. The clarifier is also equipped with oil and grease removal mechanism. It has peripheral drive mechanism for scrapping of sludge. About 50-60 per cent all the settleable solids can be removed by primary clarification. BOD is also reduced to the extent of 25 - 30 per cent.

d) *Aerobic biological treatment*

In this system dissolved starches, sugars and other carbohydrates are utilized by the micro organisms as food. In the process, more bacteria get generated and later get converted to waste bacterial solids. Proper conditions are maintained for bacterial growth through the supply of oxygen and nutrients.

e) *Activated sludge process*

The wastewater is first collected in primary settling tank where 50-60 percent of all settleable solids are separated. The clarified wastewater then flows into the aeration tank where more and more bacteria get generated. Thereafter, the wastewater flows into the secondary settling tank. A part of the activated sludge is returned to the outlet of primary settling tank. This hastens the multiplication of bacteria in the secondary tank. It is aerated in the aeration tank to keep on the bacteria multiplying. BOD removal efficiency of this process ranges between 80 to 85 percent.

f) *Trickling filter*

Trickling filter is a circular tank of about 1.8 m depth. Its width is designed on the basis of the quantity of wastewater. The tank is filled with 100-125 mm aggregates of stones or plastic balls. Wastewater is sprayed on the aggregates with a rotating arm. Microorganisms develop around the aggregates. A microbial film is formed on the surface of the aggregates. This film oxidizes the organic matter present in the wastewater. In this process you can get BOD reduction of 70 - 85 per cent.

g) *Aerated lagoons*

Aerated lagoons are simple wastewater holding basins of 2-4 m depth. The organic wastewater is degraded by aerobic microorganisms. Floating mechanical aerators are fitted for the supply of oxygen. A BOD reduction of 80-95 per cent can be achieved in this method in a retention period of 4-5 days.

h) *Waste stabilization ponds*

This is a natural process of wastewater treatment. The ponds are usually used where land is cheap and temperature is moderate. The pond depth is 0.9 to 1.5 m and area depends on the volume of the wastewater. The wastewater is treated and stabilized by a combination of aerobic, anaerobic and facultative bacteria. In a retention period of 10-40 days it can remove BOD from 80-95 per cent.

i) *Oxidation ditch*

It is an oval shaped closed channel of 1-1.5 m depth. Cage rotors are used for intensive aeration of the waste water. In retention period of 10- 40 days it can remove BOD from 80-95 per cent.

j) *Rotating biological contactors*

The system consists of concrete or steel tank through which the wastewater passes. The rotating biological contactors consist of polymeric material discs. These discs are closely spaced and mounted on a shaft. A drive motor rotates the shaft at a very slow speed of 2 - 3 rpm. The discs are submerged in wastewater tank. When the discs rotate, the wastewater passes through them continuously. The discs expose to wastewater and atmospheric oxygen alternatively. Like this a bio film develops on the disc's surface. In this process BOD reduction is achievable to the extent of 90 per cent.

k) *Activated biofilter process*

The activated bio filter is a biologically active column. It is made biologically active by the return sludge. High level concentrated suspended growth of microorganisms can be obtained in the filter. Achievable BOD removal is quite high in this filter.

l) *Combined activated bio filter and activated sludge process*

It is a combination of activated bio filter and aeration tank You can achieve best performance and economics by combining aerobic treatment process with activated bio filter. It is becoming popular due to higher organic loading rate, better BOD reduction and lower cost of construction.

II. Bio-energy production

You can utilize the wastewater obtainable from fruit and vegetable processing industries to produce bio-energy through anaerobic biological treatment.

Anaerobic biological treatment process proceeds in two steps. The first step is, degradation of organic matter or waste into volatile acids. In the second step, the volatile acids convert into methane gas. It is an improvement over the conventional anaerobic biological system which takes 30-60 days to complete the treatment process. The two-stage anaerobic reactor enhances energy production and reduces hydraulic retention time to 1-4 days. Layout of the system is shown in Figure 10.1.

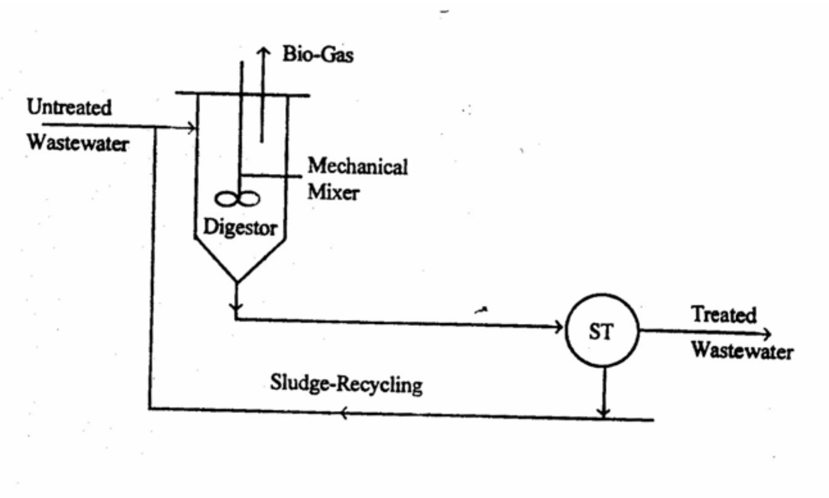

Figure 10.1: Anaerobic biological treatment

III. Utilization of organic solids for soil improvement

a) *Solid waste from wastewater treatment plant*

The secondary sludge obtained in these systems need drying. You can use sludge drying beds or the ground drying method. This can be used as a good quality compost for agricultural crops. You can palletize this organic waste for direct drilling along with the seeds for better production. Pelletization also helps in storage and economic transportation to distant places.

b) *Land application*

The wastewater after primary and secondary treatment becomes suitable for land application. You can use this water for irrigation.

c) *Wet land application by macrophyte treatment*

To utilize the treated wastewater artificial wet lands such as marshes and swamps are created. Floating plants, like water hyacinth, serve as mechanical filters. The wet land becomes useful to grow crops and aquatic species. Fish ponds can also be constructed for economic recovery.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is fruit and vegetable processing organic liquid waste? Why should it be treated before recycling / use?

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2. What are different methods of by-product recovery from waste water?

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3. Illustrate the method of bio-energy production from waste water.

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4. How can you utilize the solid wastes separated from wastewater? What is the advantage of pelletization.

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10.9 LET US SUM UP

The left over materials after processing of fruit and vegetables into various products are termed as waste. The waste is of two types, viz. solid and liquid. Solid wastes are peel, stone, seeds, trimmings, core, etc. Liquid waste is the wastewater coming out of the processing plant after washing, peeling, sterilizing, etc., of the food stuffs and the machinery.

The solid wastes could either be utilized as such, e.g., animal feed, or a number of by-products could be prepared. Through chemical extractions dietary fibre, pectin, pigments, etc. could be obtained. The microbial fermentation of waste could produce biogas, citric acid, vinegar, ethanol, enzymes, etc.

The wastewater from fruits and vegetable processing industries is a resource for many useful materials such as pectin, essences, alcohol, soup, feed, fuel, manure, etc. Treatment and utilization of wastewater is important both for environmental protection and economic returns. This wastewater has higher and immediate BOD because of the availability of soluble sugars which have a rapid rate of oxidation. The wastewater treatment strategy includes by-product recovery, screening for separation of solids, neutralization, oil and grease removal, equalization, and aerobic, anaerobic and combination of aerobic and anaerobic processes. The solid wastes can be palletized and used as manure.

10.10 KEY WORDS

Aerobic	:	Reaction or biological degradation in presence of air/oxygen.
Anaerobic	:	Reaction or biological degradation in absence of air/oxygen.
Activated sludge	:	Sludge with microbial activity.

Biogas	**:**	Microbial production of methane by *methanotropic* bacteria.
Biodegradable substances	**:**	The biomass convertible by microorganisms.
By-products	**:**	The products manufactured from the leftover materials obtained during processing of fruits and vegetables.
BOD	**:**	Biological oxygen demand measures amount of O_2 required by acclimated microorganism to degrade organic matter biologically.
Cloud	**:**	Unprecipitable suspension of the insoluble essential oils, pectins, lipids and proteins in juice.
Cider	**:**	A product obtained after fermentation of pomace.
COD	**:**	Chamical oxygen demand.
Dietary fibre	**:**	Insoluble hemi cellulose and cellulose, obtained from wastes.
Molasses	**:**	Concentrated form of pre treated juice.
Microbial pigment	**:**	The colour obtained by microbial fermentation of fruit and vegetable wastes is termed as microbial pigment.
Pulp wash	:	Residue obtained by washing the pulp.
Peel seasoning	**:**	Carefully cleaning and drying of peel at low temperature for maintaining the volatile oils.
Pulp wash concentrate	**:**	Evaporated juice or strong liquor up to 50-65°Brix.
Residue	**:**	Leftover materials during consumption and processing.
Single cell protein	**:**	It is microbial biomass used as food supplement.
Strong liquor	:	Liqour obtained during multi-stage extraction of pulp wash having TSS between 4-7°Brix.
Spent pulp	**:**	Residue of pulp wash after extracting strong liquor.
Wastes	**:**	The culled, undersized, disfigured, substandard, spoiled, injured, unmarketable surplus of fruits and vegetables and the leftover materials during by-products utilization including washing are termed as waste.
Whole juice cells	**:**	Juice containing vesicles or sacs.

10.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. • Wastes are of two types – solids and liquid.
   • Solid wastes are peel, pomace, seed trimmings, core, etc.
   • Liquid waste is the wastewater coming out of the factory after washing fruits, vegetables, machinery, etc.

2. Important food products are fat, starch, magaz, tutti-frutti, jam, jelly, marmalade, chutney, pickle, amchur, flavour, cheese, halwa, health flour, etc.

3. Important industrial products are oils, essential oils, pectin, colours, varnish, surfactants, fibre, glucosides, citric acid, paper pulp, etc.

4. Fat ---*Mango kernel* ; Starch---*Mango kernel;* .Magaz---*Musk melon;* Natural colour---*Blue grape skin;* Essential oil---*Citrus waste;* Amchur---Dropped m*ango;* Cheese---Guava waste; Health Flour---Jack fruit seeds.

Check Your Progress Exercise 2

Your answer should include the following points:

1. Important wastes are peel, pomace, seed, leaves, trimmings, core, etc.

2. Wastes such as banana peel, mango peel, mango seed kernel, citrus and tomato seeds are used as poultry feed.

3. Skin and ends of the pineapple constitute the bran. There are two types of pineapple bran, i.e., wet and dry.

   • The wet bran is prepared by macerating ends and skins and then pressing.
   • Mechanical and natural drying of bran constituents resulted in dry bran.

4. • Molasses is the concentrated form of pressed liquor obtained by treating waste with lime.
   • Raw materials used are peel, pomace, trimmings etc., obtained after processing of mango and citrus fruits.

Check Your Progress Exercise 3

Your answer should include the following points:

1. • The water washings of the pulp remained after juice extraction is known as pulp wash.
   • The solids extracted in the water wash are termed as pulp wash solids.

2. • Juice pulp is the ruptured juice vesicles or floating pulp obtained during juice recovery.
   • It is used for blending in juice concentrates.

3. • The juice sacks are the by-product obtained from the juice of grape fruit and lemon.
   • The juice sacks are dried and used in dry beverages mixes, jams, sauces, cookies, etc.

Check Your Progress Exercise 4

Your answer should include the following points:

1. The important products obtainable from organic waste substances from fruits and vegetable processing industries are single cell protein, animal feed, ethanol, enzyme, pigment, pectin, flavour, etc.

2. The vinegar can be produced from mango peel and stones by double fermentation. The TSS of these wastes is increased by adding came sugar and fermentation is done with *Saccharomyces cerevibial* and immobilized *Acetobacter acet*.

3. The protein supplement obtained from microbial growth and microbial biomass are called SCP. The protein content can be enhance and upto 35 per cent. The microorganisms used for SCP production are *Trichodemia uiride, A.niger, Candia utilis, Fusarium* sp, *A. tomari, S. cerevisiae, S. fibuliqer.*

4. The pigments that are produced through microbial fermentation on fruit and vegetable wastes are called microbial pigments. The microorganism like *Rhodotorula, Cruptococcus*, etc. are known to produce pigments.

Check Your Progress Exercise 5

Your answer should include the following points:

1. • The wastewater discharged from processing industries contain organic matter which have high BOD values.
   • If the waste is discharged without treatment it will deplete the dissolved oxygen.

2. • Screening or Removal of Solids
   • Oil and Grease Removal
   • *Primary Clarification*

3. • The process of bio-gas generation
   • Labelled sketch of the system and its working (10.1)

4. • The separated solid waste could be used as compost.
   • Palletization helps in storage and transportation.

10.12 SOME USEFUL BOOKS

1. Kalia, Manoranjan and Sood, Sangeeta (2000) Food Preservation and Processing. Kalyani Publishers, Ludhiana.

2. Kaushik, Vijay (2000) Food Science and Nutrition. Mangal Deep Publications, Jaipur.

3. Verma, L.R. and Joshi V.K. (2000) Post Harvest Technology of Fruits and Vegetables. Volume I and II Indus Publishing Company, New Delhi.

4. Wills, Ron, McGlasson, Barry, Graham, Dong and Joyce, Daryl (1998) UNSW Press, Australia.

UNIT 11 FOOD FORTIFICATION

Structure

11.0 OBJECTIVES

After reading this unit, you should be able to:

- list the advantages, limitations and risks in fortifying foods;
- describe the methods of food fortification;
- define the importance of fruits and vegetables in human diet;
- decide the points to be considered for fortification of fruit and vegetable products; and
- prepare fortified fruit and vegetable products.

11.1 INTRODUCTION

All living beings require nutrients to perform various functions of life. While plants can prepare them from simple chemicals present in the soil and the environment, higher organisms can not perform this synthesis and have to depend on plants and other animals for their nutritional requirements. Body performs several functions related to growth and development and it has to cope up with the normal wear and tear process. Several nutrients are required for promoting these activities which should be available in sufficient quantity. But no single food contains all the nutrients; their nature and quantity vary with the source. Improper diet may result in deficiency of one or more of these nutrients. Nutritional deficiencies reduce mental and physical efficiency of people and increase their susceptibility to diseases. It is for this reason the Indian Constitution enshrines in its Article 47 that “the state shall regard the raising of the level of nutrition --- as among its primary duties”. In this chapter we will see how fortification of fruits and vegetables could improve the nutritional status of people.

11.2 NECESSITY OF FOOD FORTIFICATION

11.2.1 Nutritional Requirements of Man

Human body requires at least 45 nutrients; 5 macronutrients (protein, fat, carbohydrate, water and oxygen) and 40 micronutrients, which include 13 vitamins (A, C, D, E, K and eight members of vitamin B group) and 17 minerals (Ca, Cl, Fe, K, Mg, Na, P, and S whose requirements are 1 µg to 1 g per day, and Cr, Co, Cu, F, I, Mn, Mo, Se, and Zn which are required in traces). Water and oxygen are not regarded as nutrients because they are present in foods and readily available for body use.

Nutrient requirements vary from person to person and are influenced by factors like age, sex, height, physiological state, physical activity and environmental conditions. No single food contains all 45 nutrients. Food items included in daily diet should be carefully selected so that the nutritional requirements are fulfilled.

11.2.2 Pattern of Food Consumption in India

In order to survive, man's main effort in ancient times was to collect enough food for his requirements and store them for difficult periods. But he soon realized that foods from different sources differ in nutritive value. Through experience over ages, he selected his foods carefully to meet his nutritional requirements and to ensure a good health. It led to the development of dietary habits. Food habits were also influenced by the foods available in the locality and practices prevalent among them.

Indian Council of Medical Research has divided the foods consumed in India into five groups: (1) cereals, grains and their products, (2) pulses and legumes, (3) fruits and vegetables, (4) milk, meat, egg and their products, and (5) fats and sugars. Cereals constitute major part of the Indian diet. Being rich in carbohydrates, they contribute up to 80 per cent of daily energy intake and about 50 per cent of daily protein intake of an average Indian. They are also dietary source of minerals like calcium, iron and vitamin B.

Pulses and legumes are the major source of proteins in the Indian diet. They are also rich in vitamin B.

Fats and oils and sugar/jaggery serve essentially as source of energy. They improve palatability of foods. Further, fats and oils provide essential fatty acids and act as carrier of fat soluble vitamins. For a good health, maximum of 20 per cent calorie requirements should be derived from fats and oils.

Milk holds a high place in the Indian diet. Milk proteins are of very good quality. It is rich in calcium and riboflavin and is a good source of many other nutrients. But it is deficient in iron and vitamin C.

Fruits and vegetables are rich in vitamin C, beta-carotene, crude fibre and minerals. In general, they are not regarded as a good source of calories and proteins; dried fruits, tree nuts, olives, avocado, beans and peas are some of the exceptions to this. Roots and tubers like potato, tapioca, yams, sweet potato, etc., contain substantial amount of starch and thus contribute substantially to the dietary calories.

Eggs and meat are good source of proteins and vitamins of group B. Their proteins are of very good quality. They are rich in calcium and riboflavin and are good source of many other nutrients.

11.2.3 Strategies to fulfil Nutritional Requirements

Inadequate and insufficient diet may result in deficiency of one or more of these nutrients. Often deficiency of one nutrient results in incomplete utilization of other nutrient(s) present in food. Nutritional deficiencies observed in India are: (i) protein-calorie malnutrition, (ii) vitamin A deficiency, (iii) iron deficiency, (iv) iodine deficiency, and (v) deficiency of vitamins of group B.

The challenge of nutritional deficiency can be overcome by increasing availability of nutrients through higher and diversified production of food and careful planning of diet. Diet planning becomes complicated because (i) foods differ in their nutrient composition, (ii) method of processing/preparation may cause losses, (iii) foods may suffer from certain deficiencies specific to a region such as iodine deficiency in Sub-Himalayan region, (iv) certain group of people may have special requirements of some of the nutrients, and (v) economic status of a group of people or population may limit the choice of food items. Further, all the nutrients present in a food may not be biologically available due to (i) the presence of anti-nutritional factors like trypsin inhibitor, (ii) their poor solubility, (iii) destruction of nutrients in the gastrointestinal tract, (iv) poor digestibility of a food source, or (v) varying degree of losses during preparation/processing.

Other methods of controlling malnutrition are (i) nutrition education, (ii) dietary diversification, (iii) dietary supplementation, and (iv) food fortification. Nutrition education and dietary diversification take long time to show results. Dietary supplementation is a very effective method but it is used in the cases of acute deficiencies in high-risk groups and is expensive. Food fortification is a simple and inexpensive method of fighting the problem of a nutritional deficiency prevalent in a known region or segment of population.

11.3 FOOD FORTIFICATION

The term food fortification is defined as a process of adding one or more dietary essentials to a food. Various terms are used to describe the process of addition of nutrients to foods which are discussed below.

i) **Enrichment:** This term is used for a process in which the level of one or more nutrients, already present in a food, is moderately increased by addition to make its level higher so that it becomes a richer source of that nutrient.

ii) **Fortification:** According to WHO fortification is the addition of nutrient(s) to a food or an article of diet to improve the quality of the diet of a group, community or a population. Level of nutrients added may be more than those found in original or comparable food. Objective of fortification is to help correct nutritional deficiencies in a specific population. Fortification may also include addition of small quantities of nutrient to improve intake of that nutrient by a population.

iii) **Nutrification:** It is a general term used to indicate the practice of adding vitamins and minerals to compounded and processed foods used as entire meals or meal-replacers, viz., infant formulas, instant breakfast foods etc.

iv) **Restoration:** Loss of some of the nutrients takes place during handling, transport, processing and storage of foods which can not be prevented. Restoration refers to the replacement of the nutrients lost during the above processes.

v) **Standardization:** There may be natural or seasonal variations in the nutrient composition of foods. The term standardization refers to the process of adding nutrients to compensate for the above variations and bring them to a predetermined level. It is helpful in meeting the requirements of nutritional labelling.

vi) **Supplementation:** This term refers to the process in which nutrients not present normally or contained only in very small quantities in a food, are added to it.

The above terms are often used interchangeably. Fortification is now a general term used to indicate addition of nutrients to improve nutritional quality of foods.

11.3.1 History of Food Fortification

Probably the earliest recorded attempt of fortification is of 4000 B.C. when the Persian physician Melamus prescribed a diet including sweet wine laced with iron filings for the sailors. In 1833 a French chemist Boussingault advocated addition of iodine to table salt to prevent goiter in South America and thus may have introduced the concept of "food fortification". Another important observation was made in 1897 when Dutch army doctor Eijkman while working in Indonesia, noted that beriberi was more common in people whose staple diet was polished rice. Vedder and Williams used a crude extract from rice bran, to cure advanced cases of beriberi despite the fact that they were unaware of its active constituent. In 1911, Funk established that the anti-beriberi compound of unpolished rice was an amine. He named this compound as vitamine, i.e., vital amine. Williams continued his work in Philippines and synthesized it. Since this amine contained sulphur, he named it as thiamine, i.e., sulphur amine. A Swiss company, Hoffman-Roche developed a process for adding thiamine, niacin and iron to rice.

Introduction of margarine, a butter substitute, in Denmark led to vitamin A deficiency. Therefore, fortification of margarine with vitamin A was started in 1918. Fortification of flour with thiamine, riboflavin, and niacin and sometimes iron and calcium was started in the United Stated of America during World War II. Addition of vitamin D to infant formulations and milk and dairy products to prevent rickets among children are other examples of early efforts of food fortification.

In India, fortification of salt with lysine, iron and vitamin A was tried in 1970. At present, several food products available in Indian market are fortified, viz., common salt is being fortified with iodine salts, vanaspati with vitamins A and D and bread with lysine. For fortification of salt with iodine, potassium and sodium salts of iodide and iodates are used. They are added at the rate of 30-200 mg per kilogram of salt, depending on the amount of salt consumed per day by a population. In India, salt consumption is 15 gm per day per person. Therefore, potassium iodate is added at the rate of 15 mg per kilogram of salt.

11.3.2 Advantages of Fortification

Food fortification does not require people to change their dietary habits and it does not alter organoleptic qualities of foods. Therefore, it is socially acceptable. The other benefits of fortification are (i) minimum risk of excess intake of the nutrient, ii) safe, quick and cheap method of ensuring availability of a nutrient, (iii) introduction through existing marketing and distribution system without any extra effort, (iv) every segment of affected population gets necessary amount of the nutrient, and (v) synthetic nutrients used in food fortification become available just after their absorption in the intestinal tract.

11.3.3 Limitations of Food Fortification

Food fortification requires knowledge of dietary habits and nutrient intakes in the target group(s). Consumers have to be educated about fortification, particularly if it is causing any change in the sensory qualities of the food or it necessitates any modification in the method of preparation of food at home. Food fortification is a temporary method of improving nutritional status of the people and should ultimately be substituted by balanced diet based on better food supply and food usage.

11.3.4 Safety of Food Fortification

Excessive intake of nutrients may sometimes lead to undesirable interactions with other nutrients. For example, excessive intake of an inorganic element can depress the absorption or utilization of another. Similarly, excessive intake of a strongly reducing nutrient, like vitamin C, can reduce absorption of selenium or carbon and strongly enhance bio-availability of iron. Higher intake of fat-soluble vitamins A and D exert toxic effect, while other vitamins are non-toxic even if ingested at high levels (up to 100 times of recommended level). The safety range is smaller for vitamin A (10 times of RDA) and iron (5 times of RDA). Level of food fortification generally ranges between 15 to 25% per serving, which is much below the critical levels.

In fortified food products, the level of fortification must be documented. Level of nutrients which amount to excessive intake should be established scientifically and the consumers should be made aware of such levels and their adverse effects. Response of consumers on quality of fortified foods, nutritional benefits or other relevant information must be collected and used to improve the product.

11.3.5 Methods of Fortification

Methods used for food fortification with nutrients are as follows:

i) *Dry mixing:* It is used for foods like salt, beverage powders, cereal products, milk powder, etc.

ii) *Dissolution in water:* The nutrients are dissolved in water or the product and mixed, e.g., fruit juices, beverages, drinks, etc.

iii) *Spraying:* Processed foods that require cooking or extrusion like potato chips, fruit bars, etc.

iv) *Dissolution in oil:* Oily products such as vanaspati are enriched by nutrients dissolved in oil.

v) *Adhesion:* It is used for sugar fortification. Vitamin A in powder form is adhered onto the surface of the sugar crystals when used with a vegetable oil.

vi) *Coating:* The vitamins sprayed over the grain must be coated to avoid losses when they are washed before cooking. It is generally used in case of rice.

vii) *Pelleting:* It is also used for rice. The vitamins are incorporated into pellets reconstituted from broken kernels.

11.4 FORTIFICATION OF FRUIT AND VEGETABLE PRODUCTS

Fruits and vegetables posses rich colour and have varied aroma. They add variety to the food, and improve aesthetic appeal of the diet. Fruits and vegetables are generally consumed for their aesthetic appeal but their nutritional significance is not fully realized by the consumers. They are rich sources of vitamins, minerals and dietary fibre. Dietary fibre (hemicelluloses, celluloses, lignins, oligosaccharides, pectin, gums and waxes) though resistant to digestion play an important role in human health. They do not provide nutrients directly, but low dietary fibre have been associated with diseases like cardiovascular diseases, obesity, diabetes, constipation, bowel cancer, etc. Daily intake of 30 g dietary fibre by a normal healthy adult has been suggested. Fruits and vegetables, in general, contain 1.0 to 2.2 % fibre and contribute up to 50% of dietary fibre. Fruits and vegetables, contribute about 90% of total dietary ascorbic acid, 50% of vitamin A, 35% of riboflavin, 25% of magnesium, 20% each of thiamine and niacin, 20% of fat, 7% protein and 10% of food energy.

Nutritional composition of fruits and vegetables depends on species, variety, location, season and agro-climatic conditions. Moreover, nutrient loss also occurs during storage, preparation and processing. Consumer may not be aware of these changes. Fortification helps in standardizing fruit and vegetable products to a pre-decided level of nutrients. It also enables processors to fortify the products to meet the nutrient requirements of specific group of people such as sport persons and athletes.

11.4.1 Principles of Fortification of Fruit and Vegetable Products

Following points are to be considered before fortifying a product:

1. *Principle of need:* There should be a deficiency/ malnutrition in a population which makes food fortification necessary.

2. *Principle of food distribution:* A proper carrier should be identified for fortification programme. Any such carrier that is consumed by a large population should be centrally processed and centrally distributed. Fortified food should be made available to the people who need them at their place.

3. *The principle of stability:* Nutrients should be stable during processing, storage and distribution. To compensate for these losses an overdose of nutrient is added. But for determining overdose, the maximum amount of

particular food likely to be consumed by an individual per day should be known, and it must be ensured that there is no excessive consumption of nutrient.

4. *Principle of compatibility:* Nutrient being used for fortification should be physiologically and chemically compatible to natural or other food ingredients. It is very important that the added nutrient does not react and remains biologically available.

5. *The principle of camouflage:* Fortification should not cause noticeable changes in sensory characteristics of food products. This is an important point to be considered during fortification.

6. *Principle of economy:* Cost of a fortified product is influenced by the cost of nutrient added, form of the nutrient, shelf life of the product and overages needed to achieve a specified shelf-life. Fortification should not make much difference in the cost of the food product.

7. *Principle of accessibility:* Standards and specifications for fortified food and methods of enforcing them should exist.

8. *Principle of disclosure:* The form and amount of nutrient used for fortification should be declared on the label so that the consumers could know it.

9. *Availability of technology and equipment:* Fortification on commercial scale requires special equipment, proven technology and skilled manpower. They should be available.

11.4.2 Fortified Fruit and Vegetable Products

Fruit and vegetable products generally selected for fortification are those which are consumed more regularly and therefore, can serve as a better carrier of nutrients. Beverages, juice concentrates, juice powders, fruit bars, jellies and jams are a few examples of such products. Fortification should ensure that the normal amount of that food product consumed in a day supplies the whole requirement of the consumer for that nutrient.

Retention of nutrients in fruit and vegetable products are affected by the conditions prevailing during processing and storage. Therefore, sufficient overdose should be added to these products.

Information about the nutrient content is given on the label of container on the basis of a serving. The term ‘serving’ denotes that quantity of a food in a meal which is suitable for consumption by an adult male doing light physical activity. Unit of ‘serving’ should be understandable to common consumer, such as cupfuls, teaspoonfuls, etc.

11.4.3 Fortification of Beverages

The term beverage includes fruit juices, squashes, nectars, ready-to-serve beverages, carbonated beverages or aerated waters, synthetic juices, fruit juice concentrates and dry instant drinks. Beverages are the most commonly fortified fruit and vegetable products. They are fortified with vitamin C and to some extent with vitamins A and B. For vitamin A, the substance used is beta carotene, which is a precursor of this vitamin and also gives colour to the juice.

Synthetic sources of vitamins are used, though blending with aonla juice as a source of vitamin C and carrot juice as a source of beta carotene can also be carried out. Losses of vitamins may take place during processing. Therefore, contact of fruit juice with iron and copper should be minimized by using stainless steel or glass lined equipments and vessels and juice should be de-aerated before pasteurization.

Vitamins, particularly thiamin, folic acid and vitamin C, are sensitive to heat. Beverages fortified with these vitamins must not be over heated; their temperature should be kept at 90^0C or less for a maximum period of 15 seconds. Fortification of beverages with vitamin A, folic acid and calcium pentothenate present problems because these nutrients are very unstable at pH around 3.0, which is normal pH of most fruit juices. Further, solubility of folic acid in water is very low.

Vitamin premix is dispersed in juice/ beverage, before homogenization step. Subsequent step of homogenization insures thorough mixing of vitamins in beverage.

Amount of vitamin C added should be such that each serving of 110-170 ml provides about 40 mg, which is the minimum daily requirement of an adult. Since some of the vitamin C may be lost during processing and storage, its 35-70% extra amount is added. In other words, total amount of vitamin C should be 54 to 68 mg per serving.

i) Fortified apple juice

Apple juice contains only 0.2-0.6 mg vitamin C per 100 ml as compared to 9.7-70.0 mg per 100 ml in orange juice. Further, colour of apple juice is light after extraction. But colour of juice becomes dark within 1 hour due to action of enzyme polyphenol oxidase on tannins of juice in the presence of air. Apple juice is fortified with vitamin C to raise its vitamin C content and to utilize oxygen present in the head space. Removal of oxygen from headspace checks oxidation of tannins and thus prevents discoloration of juice. But fortified apple juice, when exposed to oxygen, starts loosing vitamin C at the rate of 1 to 4 mg per 100 ml per day and its colour may again become dark. Therefore, it should be protected from air.

Vitamin C is added at the rate of about 70 mg per 100 ml at the time of extraction when apple juice comes out of press. Excess amount of added vitamin C may get degraded during processing and storage but it ensures that 40 mg of this vitamin per 100 ml remains in the juice.

ii) Fortified orange juice

Vitamin C content of orange juice varies from 27 to 67 mg/ 100 ml depending upon location of orchard, variety, etc. Therefore, orange juice is fortified so that it provides the minimum recommended amount of 40 mg vitamin C per serving.

iii) Fortified fruit juice concentrates and powders

Fruit juice concentrates and powders serve as base for various fruit beverages. They are easy to store and transport and reduce packaging requirements as compared to juices and other beverages. But during preparation, fruit juices are heated for long period which results in greater loss of vitamins. Therefore, they are fortified. High TSS of concentrates protect vitamins and reduce loses during storage. Synthetic orange juice concentrates are prepared using orange pulp and rind. Other ingredients added are gum *arabic*, cellulose gum, natural and synthetic flovours, artificial colour, potassium citrate and calcium phosphate. It is fortified with vitamin A, B and C.

Fortified fruit juice powders are prepared from fruits like apple, peaches, cherry, etc., by foam-mat drying process. In this process solubilized soy protein and methyl cellulose is added to fruit pulp.

Instant dry mixes of beverages and juice powder are fortified with vitamins by dry mixing. Water dispersible forms of vitamins are used. Mixing must be complete but over mixing should not be done because it results is segregation.

iv) Fortified carbonated beverages

Many carbonated beverages are fortified with vitamin C. During carbonation process, CO_2 expels the air. Removal of air and oxygen increases stability of this vitamin. Fortification of carbonated beverages with vitamin C improves nutritional value of the beverage, and some of it react with and remove residual oxygen from the head space of bottle which extends shelf-life of the beverage. Theoretically, 3.3 ml of vitamin C reacts with 1 ml of air. An overdose of vitamin C should be added to carbonated beverages to compensate for the losses.

v) Fortified banana powder

Banana powder fortified with soy protein can be used as a weaning ford for babies. To prepare it, whole soybeans are blanched in boiling water for 30 min, ground into fine paste with 10 times its weight of water and mixed with ripe banana pulp. Ratio of banana solids and soy solids in paste is kept equal. To the blend 100 ppm sodium meta bi-sulphite is added which prevents darkening. The paste is dried to 3% moisture level over a drum drier.

vi) Fortified jellies

To fortify jellies, a concentrated vitamin premix is prepared and some sucrose is added. Fat soluble vitamins are used in water dispensable forms. Vitamin premix is added to the jelly near the end point but before addition of citric acid. Vitamin C reduces the pH of jelly which may prevent their setting. Therefore, pectin jellies are not fortified with vitamin C.

vii) Fortified fruit cloth and fruit bar

Fruit cloth and fruit bars are products prepared from fruit pulp and concentrates by sun drying or drum drying. Fruit clothes from apples, apricots, dates, mango, papaya, etc., are prepared. 'Amavat' or 'Ampapar' is traditionally prepared in India by sun drying ripe mango pulp in the sheets, the thickness of sheet is gradually increased. The fruit bars can be moulded into different forms. They may be pre-treated with SO_2, viz., 0.5% sodium bisulphite. Sulphur dioxide improves colour and protects vitamin C and beta-carotene. Level of total soluble solids in pulp is raised to about 30% by adding sugar, also reduces drying time. Depending upon requirement, citric acid is added to improve the taste and acceptability of fruit bars. It can be fortified with protein powders (skim milk powder, whey protein isolate, ground nut or soy protein isolate, yeast protein), vitamins and other nutrients. Fortification is done by adding nutrients to the pulp concentrate and then drying it or spread the nutrient premix over the surface of dried fruit material.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. How has ICMR classified foods consumed in India?

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2. Define term 'food fortification'.

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3. What points should be considered before taking up food fortification work?

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4. What is significance of fruits and vegetables in human nutrition?

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5. What are the advantages of fortifying carbonated beverages with vitamin C?

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6. At what stage vitamin C and vitamin pre-mix should be added to apple juice, instant juice powder and fruit jelly?

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7. Discuss the factors which influence stability of vitamin C and beta-carotene in fruit and vegetable products.

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11.5 LET US SUM UP

Nutritional requirements of men are varied and no single food can provide all the dietary essentials. It has resulted in various types of nutritional deficiencies. In such cases fortification offers an inexpensive and quick method for combating problem of nutritional deficiencies. People should be educated about needs and benefits of food fortification. Commonly fortified fruit and vegetable products are beverages, fruit bars and jellies which are consumed by a large section of people. Essentially fortification should be done only when it is necessary as proved by scientific studies, should be safe and effective. It should not be used as a marketing strategy.

11.6 KEY WORDS

Beverages	:	This term includes fruit juices, squashes, nectars, ready-to-serve beverages, carbonated beverages, synthetic juices, fruit juice concentrates and dry instant drinks.
Dietary fibre	:	It is that part of plant food which is resistant to digestion in the human beings.
Fortification	:	It is defined as a process of adding one or more dietary essentials to food.
Fruit bars/clothes	:	They are products prepared by drying fruit pulp and concentrates in the form of sheets.
Overage	:	Extra amount of nutrients added during fortification process to compensate for the losses during processing, storage and distribution.

11.7 ANSWERS TO CHECK YOUR PROGRESS EXCERCISES

Check Your Progress Exercise 1

Your answer should include following points:

1. • Five food groups have been identified by ICMR.
   • i) cereal, grains and their products, ii) pulses and legumes, iii) fruits and vegetables, iv) milk, meat egg and their products and v) fats and sugars.

2. • It is a process of adding dietary essentials.
   • Type of nutrient(s) added, their quantity and objective of adding them.

3. • Necessity of fortification
   • Basic principles of fortification

4. • Enhancement of aesthetic appeal of the diet.
   • High amounts of vitamins, minerals and fibre.

5. • Capability of vitamin C in removing oxygen
   • Nutritional improvement

6. • Vitamin C is added at the time of juice extraction to check.
   • Oxidative discolouration in apple juice.
   • Dry mixing of vitamins to reduce adverse effects of heat on vitamins in pre-mix in instant juice powders.
   • Vitamin premix is added in jelly near the end point but before addition of citric acid.

7. • Effect of heat, pH and oxygen on vitamin C.
   • Effect of pH and oxygen on beta-carotene.

11.8 SOME USEFUL BOOKS

1. Verma, L.R. and Joshi, V.K. (2000) Post-harvest technology of fruits and vegetables, Vol. II, Indus Publishing Co., New Delhi.

UNIT 12 PACKAGING – NEED AND IMPORTANCE

Structure

12.0 OBJECTIVES

After reading this unit, you should be able to:

- state the definition of food packaging;
- define the functions of packaging and its importance;
- explain the types of packaging;
- classify various packaging materials;
- describe the properties of packaging technology and its applications in processed food products; and
- design and develop the packages.

12.1 INTRODUCTION

The term food is defined as any substance containing nutrients such as carbohydrates, proteins, and fats that can be ingested by a living organism and metabolised into energy. Food is necessary for survival, growth of physical and mental ability and good health. The need and importance of food was known even to primitive men.

The nutritional status of a nation is complicated in nature as it depends on many inter-related set of factors such as food adequacy and its distribution, levels of poverty, level of literacy, status of women, rate of population growth and the extent of economic growth. In our country, the trend of nutritional level improvement for the last fifteen years has been gradual and modest despite steep rise in population.

The Indian economy is predominant agrarian. Agriculture constitutes 33% of our GDP, supports 64% of work force and earn 19% of our exports. The country produces 46 million tonnes of fruits and 96 million tonnes of vegetables and is the second largest producer next to Brazil and China, respectively. In spite of having such a good production, it incurs a loss of 25-30% every year. The spoilage of food products are due to improper infrastructure facilities for storage, handling, transportation and unscientific and inadequate packaging. India wastes more fruits and vegetables than are consumed in a country like U.K. This indicates that there is an urgent need to give more emphasis on packaging of food.

The level of food processing in our country is very low which has to be considerably increased if losses are to be minimised and also to ensure marketing of good product in packaged form. The selling of loose and exposed product is unhygienic and affects the health of the common masses. There could be considerable amount of savings in this context if all surplus quantity of produce are processed and sold in the market in a packaged form. But, consumer awareness and education are extremely important if this has to be achieved.

Indian consumer prefers to buy fresh produce and cook at home. Generally, processed and packaged forms are less preferred and purchased by Indian consumer as compared to the market trend elsewhere in the world. The primary reason is a myth and an inertia. There is still a perception that processing reduces the nutritive value and add to the cost. This myth needs to be broken on an urgent basis. The fact is that packaging reduces waste, adds value and assures a product to the consumer.

In our country, any fresh produce fruits, vegetables or processed products have never been associated with packaging. It is only in the recent times that the importance of packaging has been accepted. This is mainly due to growing consumer awareness and their willingness to pay for quality and hygienic products. In addition, increase in growth of exports has also made it obligatory to pack the product in attractive and consumer friendly packages. Considerable amount of improvement and development in packaging has taken place, especially for food products, in the last one decade. However, these efforts need to be augmented and implemented effectively to minimise the problems and make the food available more easily and economically. It may be pointed out that there is a tremendous scope for further improvement and development of packaging. In fact, the per capita consumption of packaging materials in India is much lower as compared to other developed and developing countries. Many more food products are still available in Indian market in unpacked condition, particularly the fresh produce like fruits, vegetables, meat, fish, poultry, etc. In order to maintain the hygienic condition of these food products and also to ensure their assured quality, it would be desirable to sell these products in packaged conditions. This will also increase the consumption of packaging materials enormously.

The subject “Food Packaging” has been introduced to modern technology recently. But this technology was existent on earth without having any proper attention. Most of the fruits like coconut, orange, banana, etc., having a skin or peel are available to us in packaged form in hygienic conditions this type of packaging is considered to be natural packaging. Further, the use of dry leaves for wrapping meat, animal skin based bags for storage, etc., wherein vogue since long. But recently, the importance of packaging has been understood in the food supply chain.

Food packaging is defined as a mean or system by which a fresh produce or processed product will reach from the production centre to the ultimate consumer in safe and sound condition at an affordable price. In other words, packaging is a combination of science, art and technology. Packaging is an integral part of production, storage, handling, distribution, retailing and end-use. Packaging is also considered as the last output of production but the first input of marketing. In other words, packaging acts as a tool or instrument for marketing.

The functions of packaging is performed by 3 P's, i.e., Preservation, Protection and Presentation. The above three P's are applicable to consumer products. However, this has minor role to play in industrial products.

Packaging serves two basic objectives, i.e., marketing and logistics. In its marketing function

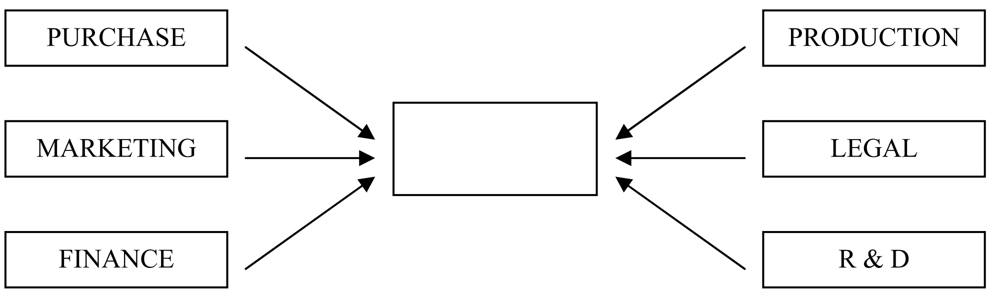
- it provides information about the product to customers,
- it promotes the product with attractive graphics and printing,
- it acts a medium of communication,
- it acts as a silent salesman and it is the final interface between the company and the consumers.

From the logistic perspective, the role of packaging is to ensure the safe delivery of a product to the ultimate customer at minimum cost.

In the logistic perspective, it performs six functions:

- Containment
- Protection
- Apportionment
- Unitisation
- Convenience
- Communication

The packaging function is closely associated with many other functions in an organisation. Effective communication is, therefore, important. In an organisational set up the packaging function is interrelated and this is illustrated below:



Due to this fact, packaging department is considered to be the nucleus in any FMCG (Fast moving consumer goods) company. The launch of any consumer product in a new package needs constant interaction among the inter departments of the company.

The package should be designed to provide efficient storage. However, its design is influenced by:

- Standardization
- Price or cost.
- Package or product adaptability.
- Protective level.
- Handling ability.
- Product packability
- Reusability or recyclability

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How do you define "Food Packaging"?

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2. What are the important functions of packaging?

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3. What are the factors involved to make a good package design?

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12.2 TYPES OF PACKAGINGS

The container or the package serves mainly as a protectional device to avoid deterioration in the quality of contents against external agencies. However, in many instances, the packages are also designed taking into account the marketing considerations such as sales appeal, easy acceptability, handling convenience and distribution factors. Hence, it is desirable that you should know about the components of packaging or types of packaging available in the market.

12.2.1 Package Components

A broad classification of package components is given below:

i) Unit pack
ii) Intermediate pack
iii) Outer or shipping container
iv) Inner packaging components
v) External reinforcements

i) Unit pack

It is considered to be a package containing single unit, e.g. a toffee or chocolate is wrapped, 200 ml beer is packed in metal container. Unit package should be able to protect the product against the deterioration of quality. Naturally, the material selected for unit pack should have adequate functional properties to serve such function. This package serves as a retail pack and thus the package should have good eye appeal, easy openability and easy to carry or handle. In short, the package should be customer friendly.

ii) Intermediate pack

The unit packs further unitised to satisfy the marketing requirement, are called intermediate packs. For example, 10 unit pack of 100 g of butter packed in paper board carton are unitised to facilitate handling and enhance display value.

iii) Outer or shipping container

The intermediate packs are further packed into corrugated fibre board boxes or wooden boxes or Jute bags or HDPE woven sacks to transport the products. These packages are also termed as transport packages. These packages provide protection to the contents from journey hazards such as shock, vibration, drops and climatic hazards like rain, dust, sea water, etc., during handling, storage and transportation from one place to another.

iv) Inner packaging components

These components are normally given to the transport package by way of providing the resistance of movement of contents during journey due to vibration. The materials like separators are used in package where glass bottles are packed. Cushioning materials like thermocole, expanded polystyrene (EPS), expanded polyethylene (EPE), paper cuttings, wood wool are used either to protect the product against the shock hazards or space fillers to prevent the movement of contents during journey.

v) External reinforcement

The shipping containers are further reinforced by means of either plastic straps or metal straps applied along the girth as well as the length in order to strengthen the shipping container. Reinforcement also helps to improve the stacking strength, avoid bursting in case of failure and increase weight carrying capacity.

12.2.2 Packaging Materials

Packaging materials are broadly classified into two major types.

i) Primary packaging materials
ii) Ancillary packaging materials

I) Primary packaging materials

a) Flexible packaging materials

i) Cellulose based materials
ii) Regenerated cellulose or cellophane

iii) Jute or hession materials
iv) Aluminium foil
v) Plastic films and laminates
vi) Plastic woven sack

(i) Cellulose based materials

These materials are available in two forms, i.e., Paper and paper board. More than 180 gsm paper is generally termed as paper board.

- Paper: Different types of paper used in packaging are:

  - Tissue paper
  - Coated (varnish or wax coated)
  - Butter paper
  - Glassine paper
  - Art paper
  - Kraft paper
  - VPI paper
  - High gloss paper
  - Vegetable parchment paper

- Paper Board : Different types of paper boards used are:

  - Coated board
  - Duplex board
  - Triplex board
  - Asphalted board
  - Grey board
  - Mill board
  - Clay coated board
  - Kraft board
  - Chip board
  - Straw board

(ii) Regenerated cellulose or cellophane

The most common types of cellophane used for packaging are:

- Moisture proof sealable transparent cellophane(MST)
- Moisture proof sealable transparent coloured cellophane (MSCT).
- Moisture proof sealable transparent anchored cellophane (MSAT)
- Moisture proof saran coated cellophane (MXXT)

(iii) Aluminium foil

Different thicknesses of aluminium foils are available for the packaging application.

(iv) Jute or hession materials

Jute fabrics of different types, like single warp and double, are used for making the jute bags. Sometimes, the jute fabrics are also made water proof either by lamination or coating with bitumen or plastic for packaging.

(v) Plastic films and laminates

There are various types of polymeric materials which are converted into plastic films and have got wide application in packaging.

Some of the important polymeric materials are as follows:

- *Polyethylene*
  - Low density polyethylene (LDPE)
  - High density polyethylene (HDPE)
  - High molecular high density polyethylene (HMHDPE)
  - Linear low density polyethylene (LLDPE)
  - Very linear low density polyethylene (VLLDPE)
  - Copolymers like surlyn or primacor (EAA)
- *Polypropylene*
  - Bioxially oriented poly propylene (BOPP)
  - Cast poly propylene (CPP)
  - Tubular quenched poly propylene (TQPP)
- *Polyvinyl chloride (PVC)*
- *Polyethylene terephthalate (PET)*
- *Polystyrene (PS)*
- *Poly carbonate (PC)*
- *Poly amide or nylon (PA)*

Depending on the requirement, the plastic films are converted into composite structure either in co-extruded form or in laminated form. The packaging materials are available either as 3 layered or 5 layered coextruded film.

- LDPE/ HDPE/ LLDPE. (3 layered co-extruded)
- LDPE/ TIE/ NYLON/ TIE/ LDPE.(5 layers co-extruded)

These types of films have got extensive application for the packaging of fresh milk and edible oil.

But for the consumer products like bakery items, snack foods, pan masala, confectionary, etc., the plastic based laminate in three or four layer are commonly used in order to meet the requirement of barrier properties against moisture, oxygen and light.

Some of the important structure of plastic laminates are given below:

Spices	:	BOPP film/ Adhesive/ LDPE. Metallised PET/ Adhesive/ LDPE. BOPP/ Adhesive/ PAPER/ LDPE.
Snack foods	:	Oriented PET/ Adhesive/ Met PET/ Adhesive/ LDPE. Oriented PET/ Adhesive/ Met PET/ Adhesive Aluminum foil/ LDPE.
Mouth refresher	:	Oriented PET/ adhesive/ Opaque BOPP/ adhesive/ Met. PET/ adhesive/ LDPE.

(vi) Plastic woven sack

Available in laminated or non-laminated forms.

b) Rigid packaging materials

The packaging materials are available in following types:

(i) Metal container – Drum, barrels, tin containers aluminium containers TFS Containers (Tin free steel)

(ii) Glass container – Glass bottle, glass jar carboys, ampules

(iii) Plastic containers – Plastic bottles, drum, barrels, jerican

(iv) Plastic crate

(v) Wooden containers – Box, crate

(vi) Corrugated fibre board boxes

(vii) Fibre drum

(viii) Ply wood container

c) Semi rigid packaging materials

The important types of packaging materials are as follows:

i) Aluminium collapsible tube
ii) Plastic collapsible tube
iii) Composite container
iv) Paper based carton

II) Ancillary packaging materials

The important types of materials which have got application in packaging are as follows:

(i)	Printing ink	–	Flexo ink, gravure ink, offset ink
(ii)	Adhesives	–	Lamination adhesive, pasting adhesive, corrugation adhesive
(iii)	Labels	–	Self adhesive pressure sensitive

(iv) Cushioning materials – Resilience, non-resilience and space fillers
(v) Strapes – Plastic metal,
(vi) Tapes – Paper tapes, plastic tapes
(vii) Nails, hooks, clips, etc.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How do you classify the package components?

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2. What are the three important types of packaging?

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3. Fill up the following blanks:

a) Full form of PET is ________________________________
b) CPP means ________________________________
c) MAP means ________________________________
d) '3P' stands for ________________________________
e) Cushioning materials are ________________________________

4. Tick (✓) the correct answer:

a) Cellophane is

i) Paper ii) Plastics
iii) Regenerated cellulose

b) Corrugated fibre board boxes are considered to be

i) Primary packaging materials
ii) Ancillary packaging materials

12.3 PROPERTIES OF PACKAGING

Packaging is an integral part of product processing and preservation. It has a direct influence on the system in respect to physical and chemical changes. The barrier properties and packaging materials play a significant role in preservation and thus, extension of shelf life of processed food product.

With the advancement of preservation technologies for food products coupled with the introduction of newer packaging materials and systems, it has been possible to introduce new generation products into the market.

Almost all types of packaging materials are used by food industry. Metal cans made of tin plate have been used by the canneries over the years. However, the thin wall tin containers, welded or cemented joint cans with lead free solders and 2 piece tin plate cans are recently introduced in the market for the packaging of fresh produce. The food products are processed at high temperature and pressure to make containers hermetically sealed. These type of containers provide about one year shelf life to the processed food.

Despite of having the difficulties of breakage and more tare weight, the glass bottles are used extensively for packaging of the processed food products. This material is non-toxic, non-reactive and high temperature resistant. The processed food like tomato ketchup is normally hot filled in glass bottles.

The use of paper board cartons as bag in box for packaging of liquid products like edible oil is widely accepted. Paper board carton with appropriate liner is used for packaging tea.

Plastic containers, because of light weight, easy availability, economical, diversified sizes and shapes and recyclablility property are widely used for food packaging.

Dual ovenable containers made of C-PET (Crystalline PET) have a high heat resistance up to 230°C. These trays can be frozen and then directly heated in the oven and, therefore, are used for packaging of ready to eat products.

High gas barrier plastic bottles are produced by co-extrusion blow moulding process or co-injection blow moulding process have got wide application in food packaging. The polyolefin materials like PE/PP bottles are commonly used.

However, the new development of co-extruded bottle made of PE or PP/ tie/ EvoH/ tie/ PE or PP are used for the packaging of edible oil, tomato ketchup, mayonnaise and salad dressings. PVDC coated PET bottles with improved gas barrier properties are used for beer and wine.

The flexible packaging materials having number of advantages are suitable for the packaging of processed food items. A wide variety of combination of packaging materials are developed to improve the barrier properties of moisture, oxygen, CO_2, and light and thus help to enhance the shelf life of food product. Recently, the application of flexible packaging materials have gone up tremendously due to their light weight, high barrier properties and cost effectiveness. These materials are used as monolayers like PE, BOPP, CPP or as composite structure like 3 layered/4 layered laminated form or 3 layered/5 layered coextruded film for the application of packaging of liquid milk, edible oil, spices, snack food, tea, coffee, etc.

In addition, there are certain innovative technologies like retort packaging, aseptic packaging which play a great role in enhancement of shelf life of processed food product. A retort pouch, made of polyester film/ aluminium foil/ cast polypropylene combination has got the property of with standing high temperature and pressure, while sterilized in the retort. This technology is very common in developed countries but in India this has recently been introduction for ready to eat products.

The introduction of aseptic technology to the Indian market has revolutionised the packaging of liquid food products like milk, fruit juices, etc.

Moreover, vacuum packaging and gas flushing techniques are very common in food packaging. Food products rich in fat tend to get rancid due to oxidation and get spoiled. However, evacuation of air from the package and introduction of inert gas like nitrogen inside the package not only retains the shape of the content but also protects from oxidation. This type of packaging is mostly used for snack food items like chips, namkeen, bhujia, etc. However, the products like tea, coffee, spices, etc., could be packed by using only vacuum packaging as the products are powder in nature to extend the shelf life at ambient conditions.

This clearly stated that different types of packaging materials and systems have got unique properties and these are to be chosen depending upon the requirement and application in packaging of various types of processed food products.

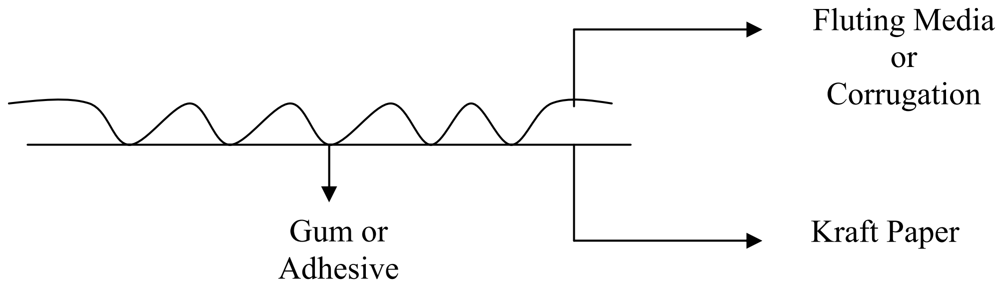
12.4 IMPORTANCE OF SUCCESSFUL PACKAGE

It is strongly desirable to keep the food products as fresh as possible for a longer duration so that these products can be distributed to a longer distance. At the same time, it is also necessary that the package has adequate strength so that the products can be transported without any breakage.

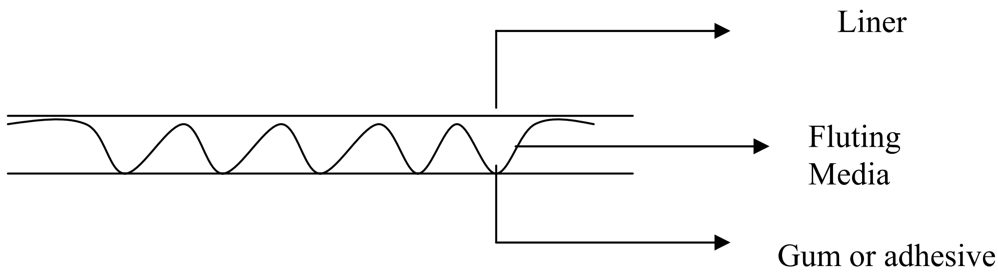
Fresh fruits and vegetables remain biologically alive even after harvest. The physiological function like respiration continues even after the supply of nutrition is cut off. The stored nutrition then begins to be consumed and gets depleted. The metabolic activity of ripening and aging also continues. Due to these facts, it is necessary to make proper ventilation in the package so that the respiration process continues, otherwise the produce will rot or spoil within a short period of time. The use of traditional packages like jute bag and bamboo basket for packaging of fresh fruits and vegetables is now being discontinued as these packages are unable to provide adequate protection to the produce during handling, storage and transportation.

The traditional packages are being slowly replaced by the use of corrugated fibre board boxes. These boxes are made from die-cut corrugated fibre board where the craft papers are passed through corrugating machine to get the fluting media or corrugation and finally stuck into a plain layer of craft paper by means of adhesives or gum to form 2 layer or 2 ply corrugation roll.

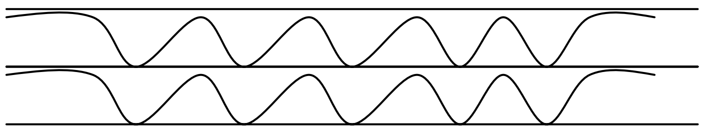
In the same manner, 3 or 5 ply corrugated fibre board boxes can be made by pasting the adequate number of craft liner or facing material. This could be illustrated by the following diagram (Figure 12.1).



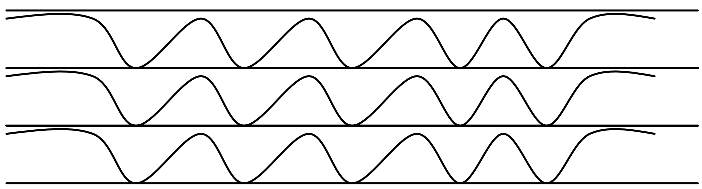
2 ply corrugating roll



3 ply or single wall corrugated fibre board



5 ply or double wall corrugated fibre board



7 ply or triple wall corrugated fibre board

Figure 12.1: Diagram illustrating different plys in a corrugated fibre board

The use of jute or gunny bag for packaging of apples is completely replaced by corrugated fibre board boxes. Similarly, the use of the bamboo busket for packaging of grapes has been discontinued and the fresh grapes are packed only in corrugated fibre board boxes. The new developed boxes are made from die-cut corrugated board with proper ventilation. The boxes are not only having adequate compression strength to prevent the crushing of fruits in stacked condition during storage and transportation but also enhance eye appeal to the consumer through attractive graphics and printing on the outer surface of the packages. The changing trend has substantially reduced the loss of fruits due to damage in transit. These examples clearly indicate that there is an urgent need to have proper package for all types of fresh produce to distribute at distant places by retaining the freshness of the produce. These are easily available, accepted internationally and can be recycled and thus considered to be environment friendly. Sometimes, the outer surface of the boxes are given adequate coating to provide moisture proofness so that packages will not be damaged even after exposing to the high humid condition.

The use of modified atmosphere technology has led to the introduction of newer plastic films, such as OPP (Oriented polypropylene) film, coated by interfacial active agent (such as charcoal) for absorbing water vapour. The other films are:

- PE (Polyethylene) film blended with microporous materials absorbing ethylene gas.
- LLDPE (Linear low density polyethylene) film blended with anti-microbial materials, preventing the growth of bacteria and mould.
- PVC (Polyvinyl chloride) film blended with silver ions for anti-microbial properties.
- Antigas barrier film having micropores which allows oxygen to enter inside the package for respiration and for prolonged shelf life.

There is a wide variety of fresh commodities and each has a different respiration rate and requirements for storage. A judicious selection of the packaging medium is thus very significant to make a successful package for fresh produce.

Similarly, there is a wide variety of processed food products which are produced by using number of ingredients and different processing technologies. This has resulted into wider variation in requirement of packaging for longer shelf life.

You know that shelf life is the time between the production and packaging of a product and the point at which it becomes unacceptable under defined environmental conditions. It is a function of the product, package and the environment through which the product is transported, stored and sold.

The bakery products like bread and biscuit, both made from maida, require different packagings to satisfy the consumer.

Bread has got moisture content of 38 to 40% due to which the crumb of bread is soft in nature and preferred by the consumer. Whenever bread is kept outside, it starts losing moisture and becomes dry and unacceptable to consumers. Hence, bread is to be packed where the packaging materials should have low water vapour permeation or high barriers to moisture content. On the other hand, biscuits are crispy in nature due to low moisture content of about 2 per cent. When the biscuits are kept outside, the product intends to pick up moisture from the environment and becomes soggy and should unacceptable to the consumers. So, the packages for biscuits also have high moisture barriers property where moisture should not move from outside to inside. The properties of foods like ghee, butter or snacks are likely to get changed during storage. The products are fried in oil and when exposed to environment, react with atmospheric oxygen and undergo oxidation. The product becomes rancid resulting into the changes in taste. Moreover, UV light also plays a role to accelerate the oxidative reaction. Hence, the packaging requirement for these items are high barriers to light and oxygen.

Aroma loss in freshly ground spice or stimulating product like tea, coffee is very common. The packaging materials for these items should have high aroma resistance property.

The requirement of packaging for different processed food is required to be understood by you prior to decide the selection of packaging materials. This is possible only by understanding the critical characteristics of the products that means how the product gets spoiled or changes its characteristics or original properties during storage.

Hence, the selection of proper packaging materials with required quality depends upon the requirement of individual variety of processed food product. Considering this, the materials are to be selected so that products can be packed to maintain the quality of food during storage. A successful package can only meet the requirement of desired shelf life of a product.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What are the important packaging materials used for processed food products?

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2. What are the different types of innovative packaging systems for extending shelf life of food products?

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3. What kind of packaging materials used for fresh produce in place of traditional packaging materials?

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4. Why the processed food products have got different packaging requirements?

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12.5 LET US SUM UP

Food is considered to be one of the basic need of human being for survival, growth of physical and mental ability and good health. This has always played an important role in the rise or fall of economy of the nation because of its effect on the health of population.

It has been reported that there has been an average loss of 25 to 30 per cent of fresh produce in our country which is mainly due to improper handling and inadequate packaging. This has forced us to understand about the importance of packaging and its needs to prevent the material loss.

Food packaging is a system by which the fresh produce or processed one will reach from the production centre to the ultimate consumer in safe and sound condition at an affordable cost. It serves two basic objectives, i.e., marketing and logistics.

The different types of packaging materials have been discussed in detail in this chapter. For processed food, the important packaging materials like metal cans, paper board carton, plastic container and plastic bottle, and flexible packaging materials with different combinations are used. Similarly, the traditional packaging materials like gunny bags or bamboo baskets are being replaced by the introduction of corrugated fibre board boxes with proper ventilation and strength for packaging, handling and transportation of the fresh produce.

In addition, the innovative packaging technologies like aseptic packaging, retort packaging, gas flushing and vacuum packaging for processed food and modified atmosphere packaging for fresh produce have also been discussed. Shelf life is the time between the production and packaging of a product and the point at which the produce first become unacceptable under defined environmental conditions.

The requirement of packaging for different processed food products varies depending on the critical factors of different products. The product requires packaging materials of having moisture barriers, gas barriers, aroma barriers or digest barrier which ultimately play a key role in determining its the shelf life.

12.6 KEY WORDS

LLDPE : Linear low density polythylene – a polymeric material.

MAP	:	Modified atmosphere packaging – a packaging system for extending shelf life of fresh produce.
C-PET	:	Crystalline polyster – a polymeric material.
PVDC	:	Poly vinylidine chloride – a coating is given to a polymeric materials to improve the barrier properties.
TFS	:	Tin Free Steel – the base plate is coated with chromium than tin.
Resilience	:	A cushioning material like sponge; it means after pressing it will come back to its original position.
Non-resilience	:	A cushioning material like expanded polystyrene or thermocole, which does not come back after releasing the pressure.
Space filler	:	Cushioning materials like paper cutting, shreded wood wool, used to fill up the space in the package.
Duplex board	:	Two layer of pulp is used to make the paper board
Triplex board	:	Three layers of pulp is used to make the paper board.
Composite container	:	A container where the body is made from paper and the ends are made from either metal or plastics.
Chip board	:	A board made on continuous machine mainly from low grade waste papers. It has got extensive use for making sweet box.
Grey board	:	A board made from mixed waste pulp with or without screenings and having the thickness less than 1 mm, used for packaging of shoes.
Clay coated board	:	High grade bending board, the top of which has been coated with fine clay to produce a surface for printing, mainly used for gift items.
Mill board	:	A homogeneous board made usually of mixed waste papers with or without screenings and mechanical pulp on an intermittent board machine and having thickness not less than 0.5mm.
Straw board	:	A board made from partially cooked straw, bagasse or grass or a mixture of these.
Glassine paper	:	Grease proof and translucent paper.
Waxed paper	:	Dry or wet waxing is done on paper to obtain the resistance to moisture and oil.

VPI paper	:	This is called vapour phase inhibitor paper. The base paper is kraft paper coated on one side with corrosion inhibiting chemical and is used for protection from rusting.
High gloss paper	:	High gloss papers are sometimes coated with metallic powder to obtain a decorative finish.
Vegetable parchment	:	Low grammage chemically bleached paper.
Butter paper	:	Grease proof paper used for packaging of butter, etc.
Retort pouch	:	A plastic based laminated pouch which can withstand high pressure and temperature.

12.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include the following points:

1. • System to deliver the food products from production centre to the consumer in safe and sound condition at an affordable cost.
   • A coordinated system which include production, storage, transportation, retailing and end use.

2. • Marketing and logistics functions.
   • To provide the information about the product to the customer and to promote the product to the customer and to promote the product with attractive graphics and printing.
   • To act as a medium of communication and a silent salesman.
   • Logistics functions like containment, protection, apportionment, unitisation, convenience, and communication.

3. 1) Standardisation — 2) Price or Cost
   3) Package or Product adoptability — 4) Protective level
   5) Handling ability — 6) Product packability
   7) Reusability or recyclability

Check Your Progress Exercise 2

Your answers should include the following points:

1. • Unit pack, Intermediate packs, Outer or Shipping containers
   • Inner packaging components
   • External reinforcement

2. • Flexible packaging materials
   • Rigid packaging materials
   • Semi rigid packaging materials

3. a) Polyethylene terephthalate
   b) Cost poly propylene
   c) Modified atmosphere packaging
   d) Protection, preservation and presentation
   e) Resilience, non-resilience and space fillers

4. a) Regenerated cellulose
   b) Primary packaging materials

Check Your Progress Exercise 3

Your answer should include the following points:

1. • Metal cans made of tin plate mainly either 3 piece or 2 piece can.
   • Glass bottles as they are non-toxic, non-reactive, and high temperature resistant.
   • Paper board carton like bag in box and lined cartons.
   • Plastic containers as they are light in weight, easily available, economical, and recyclable.
   • Flexible packaging materials like laminated film or coextruded film.

2. • Retort packaging for ready to eat products.
   • Aseptic packaging of liquid food products which have got about one year shelf life.
   • Vacuum and gas packaging for fatty foods in order to prevent oxidation process and thus extends shelf life.
   • Modified atmosphere packaging for extending shelf life of fresh fruits and vegetables.

3. • Dic-cut corrugated fibre board boxes made of either 3ply, 5 ply or 7ply.
   • Boxes should have proper ventilation to facilitate respiration process of fresh produce.
   • Adequate compression strength to resist crushing during handling, storage and transportation.

4. • Processed food products are made of different ingredients.
   • Products have got different initial moisture content (IMC) and critical moisture content (CMC).
   • Critical characters of the products are different like moisture sensitive resulting into the spoilage of products during storage.
   • The packaging materials are chosen depending on the requirement of products to prevent the spoilage and thus to enhance the shelf life.

12.8 SOME USEFUL BOOKS

1. Brody Aaron L. and Marsh Kenneth S. (1986) The Wiley Encyclopedia of Packaging Technology. John Wiley & Sons. Inc., New York.

2. Modern Food Packaging, Indian Institute of Packaging, E-2, MIDC Area, Chakala, Andheri (East), Mumbai, 1998.

3. Packaging of Food Products, Indian Institute of Packaging, E-2, MIDC Area, Chakala, Andheri (East), Mumbair, 1986.

4. Packaging Technology Educational Volumes (Part–2), Indian Institute of Packaging, E-2, MIDC Area, Chakala, Andheri (East), Mumbai, 2001.

5. Sacharow Stanley and Griffin, Jr. Roger C. (1970) Principles of Food Packaging. AVI Publishing Company, Westport, Connecticut.

UNIT 13 PACKAGING MATERIALS

Structure

13.0 OBJECTIVES

After reading this unit, you should be able to:

- describe the manufacturing processes of different packaging materials used for processed food products;
- explain the properties of packaging materials;
- discuss the advantages and disadvantages of packaging materials;
- state the application of packaging materials for different processed food products; and
- define the quality control measures of packaging materials.

13.1 INTRODUCTION

In our country, the packaging technology was not given due importance for long time but recently, the approach has been slightly changed. However, the concept of value addition to the product by means of new types of packaging materials and forms are yet to be recognised by the major quarters of population. Even today, many quarters of community consider that packaging materials always add cost to the product and thus these has been given a low priority. But with the increase standard in living and per capita income, the Indian consumers have moved to new sophistication era resulting in their demand of packaged commodities. The demand of packaging materials also have, therefore, shown a steep rise, particularly in the last three decades.

In fact, the packaging in the country appeared in the 1950's, became noticeable in the 1960's, grew in dimensions in the 1970's and with the advent of the 1980's the industry showed a tremendous progress which is continuing and likely to grow many fold in future. The poor rate of growth in the past had been attributed to lack of awareness, lack of education and skill as well as inadequate support. The other reasons could be the lack of serious attempts on standardisation of packaging materials and systems.

In the wake of industrial growth a number of industries manufacturing and marketing different range of product groups have been setup. Different kind of packages introduced over a period of time have replaced the conventional packs successfully. At the same time, industry strived its best to keep packs with the growing demand and also to cater the export requirement. Moreover, in the WTO era, it has become imperative for the Indian industry to upgrade these technologies to innovate alternate packaging materials at affordable cost to become globally competitive.

Wood, probably the oldest form of packaging medium, still dominates its use in the specific area of packaging like heavy engineering and electronics products and defence articles. But the introduction of fibre board materials like corrugated fibre board box and solid board box have completely replaced wood for the packaging of most of light engineering, automobile, textiles, etc. Today, these materials are considered to be most economical and eco-friendly.

Jute is another type of natural packaging material available in the country and has got extensive application in food grain packaging. This old age system continuing to expand with the new technologies in the combined form and has got newer applications.

Glass is a traditional packaging material. Despite its inherent characteristics like fragility, it is still in use in packaging of processed products due to its reusability.

The indigenous production of tin plates have reduced the import of these materials substantially. But the growth of these materials have been slow due to their expensiveness as compared to other packaging materials like plastics.

Plastics have entered in the packaging scene only from the mid fifty's and early 1960's. These particularly referred to low-density polyethylene and PVC. Subsequently, high-density polyethylene, polypropylene and polyester were introduced. Although, the thermosets were used earlier for caps and closures, but these are being replaced by thermoplastics. In our country, a great revolution has occurred due to the introduction of plastic carry bags in the late 70's and early 80's. Further to this, plastics by virtue of versatility have captured the market in a big way. Meanwhile, the concept of consumerisation has also played a great role in the usage of more plastics for packaging of rice, atta, maida, salt, etc. In addition, plastics packaging materials have entered in the applications of newer systems like blister and skin packaging for processed food, pharmaceuticals, shrink packaging for unitisation, strip packaging for medicine and thermoformed containers for ready to serve food products. With the same pace of development, plastics multilayered collapsible tube has also been introduced in the Indian market for the packaging of toiletries, cosmetics and processed food also.

Aluminium is used as sheets, slugs for collapsible and rigid tubes for packaging pharmaceutical ointments and for foil for making flexible laminates to pack processed food products.

The constant increase in consumer demand has forced to introduce newer packaging system for extending shelf life of food products like fruit juices. One of the most important system, like aseptic packaging system, had been introduced in our country during the early 1970's. Though, there had been certain initial inertia of consumer to purchase these packages due to prohibitive cost but slowly, its advantages were realized. Now, this system has been well accepted and more and more liquid and paste food products are being packed.

In short, packaging is a need based technology. The need of consumer forced to develop newer packaging materials as an alternate media and thus, a wide variety of packaging materials have been invented. But there is always a thrust to develop newer packaging materials at lower price so that more variety of products could be made available in packaged form. The consumption of packaging materials will increase substantially in the years to come.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write down in chronological order of appearance of packaging materials in the country.

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2. Please tick mark (✓) the correct answer.

a) Which of the packaging material is considered to be the oldest one?

i) Plastics
ii) Wooden container
ii) Paper

b) Which of the packaging material have really gone ahead as compared to others?

i) Aluminium container
ii) Plastics
iii) Glass

c) The most important natural packaging material available in the country is

i) Tin container
ii) Glass
iii) Jute

13.2 GLASS CONTAINERS

Glass, the oldest packaging material, is used as container for over 3000 years. The first glass container was made in Egypt in 1500 B.C. During the first golden age, the Romans produced some exquisite glass ware including containers. This very ancient packaging material has withstood the challenges and competition with many types of packaging materials and the same is being continued till date. With the fast development of science and technology all over the world, newer types of packaging materials like metal, plastic, etc., have been developed resulting into stiff competition with the application of glass containers in packaging. Hence, the use of glass containers have been reduced to a great extent. Despite of having certain inherent characteristics like fragility, tare weight, the glass containers have made an established application in packaging to certain specific areas like carbonated and alcoholic beverages, perfumes, etc. This is mainly due to its certain unique properties which have made it to take a lead over other packaging materials.

I. Properties

a) Chemically inert

It has no inherent property of action which enables the packaging of products without any danger of reaction or spoilage.

b) Non-permeable

Glass does not allow gases, odours, vapours and liquids to pass through its walls.

c) Transparent

You can see the packaged product.

d) Mouldable

Glass containers can be moulded easily in any shape or size ranging from a tiny vial to a 18 gallon carbouy.

e) Strength

The ultimate strength of glass is equal to that of the strongest sheet.

g) Light weight

Glass is as light as aluminium roughly 1/3rd the weight of steel or of a density 2 1/2 times that of water. Progressively, the weight of a given capacity glass container is being reduced by suitable change in design and uniform distribution of glass for increasing the strength of the container.

h) Unlimited supply

Glass container can enter to an unlimited market because of its basic raw materials – sand, lime stone and soda ash which are available in plenty. Arsenic, selenium and cobaloxides are used to make clear glass. Carbon and sulphides are added to make brown (amber) coloured glass. Boron addition provides strength to glass.

II. Advantages

a) This packaging material is used for all types of products like liquid, powder, paste, granules, etc.

b) Glass has got high and low temperature resistance. The processed food products like tomato ketchup is filled hot and can be refrigerated too.

c) Glass containers do not contaminate the contents with crystals or fibres as found in packages made of metals or alloys.

d) Climatic variations do not affect the glass container or the product packed in it.

e) Due to see through property of glass containers, the colour, appearance and consistency of the product can be easily detected.

f) Containers can be made in any size, shape and capacity depending on the requirement.

g) The glass container does not taint, pollute or affect the quality of product packed in it.

h) The closures made of metal, plastic, cork or rubber, depending up on the requirement, can be chosen.

i) Glass containers are impermeable to moisture and gases.

j) Glass containers may be coloured (like brown, green, blue) to protect the product from sum light.

III. Applications

Glass containers have wide applications in the packaging of pharmaceuticals, dairy, liquor, breweries, food, soft drinks, cosmetics, chemicals, inks and other industries. More specially, glass containers are used to pack jams, jellies, squashes, pickles and other preserves. In addition, containers are also used for processed meat and fish products, tea, coffee, spices, baby food, cheese, ghee and vegetable products.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the constituents of glass?

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2. How do you explain the important properties of glass containers?

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3. Mention the important advantages of glass packaging.

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13.3 METAL CANS

Metal cans could be made either from aluminium, tin plate or tin free steel. But the tin plate containers and aluminium containers have got extensive application in packaging. The most popular form of metal containers is tin plate container which has been used in food packaging for the last five decades. Most probably, this packaging material could be considered to be oldest one, next to glass containers, for food packaging industries.

There are two types of tin plate containers namely:

a) Open top container
b) General line container

a) Open top container

This range of containers is a standard variety from which a customer selects the size suitable for its requirement. These are also called as open top sanitary (OTS) cans and are essentially round in shape. A standard open top can is supplied by can making company with bottom seamed to the body and the top ends are supplied as loose. The processed food manufacturer fill the content into the tin can and then seam with the top lid by using a machine called seamer and then the filled tin cans are subjected to heat process. This can is also called as 3-piece can. Open top sanitary cans are widely used for processed food and beverages. One of the recent developments in open top market is the advent of easy open end. This is specially designed and accurately made to components of the can, which is made either of tin plate or aluminium. It is fitted with a "ring pull tab" whenever the customers pull the ring, it gets tear and open the top lid without much efforts. This development has definitely helped the consumer to get away from the traditional method of opening the can with the help of a 'can opener', which requires more time in opening the periphery of the top. Recently DWI can or "Drawn and Wall Iron" can has been developed. These cans are called two piece cans as the cylindrical body and bottom become single piece and lids are separate. These cans score more over conventional 3-piece cans in terms of savings of considerable amount of materials without sacrificing the speed of the machine. But these cans are confined to the applications of pressurised beer and beverages.

b) General line container

General line containers range from tiny containers like pharmaceutical ointment to 15lts capacity containers for vanaspati or biscuits and 20 litre drum for paints and varnishes. A large number of tailor made sizes of containers are added into this category. These containers are round as well as un-round (known as irregular) and are filled with various kinds of fitments made from tinplate, aluminium and plastics. These containers do not have much application for processed foods, rather bakery products, hydrogenated oils and confectionery items are packed in them.

Application

Tin plate containers have got extensive application in packaging of different products like:

i) Beer and beverages
ii) Processed food
iii) Lubricants
iv) Tooth powder/ Talcom powder/ Creams
v) Confectionery
vi) Edible oils
vii) Coffee, baby food and chocolate
viii) Aerosols
ix) Paints
x) Insecticides and pesticides
xi) Thermos flask
xii) Battery cells

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the different types of metal cans?

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2. How do you differentiate between OTS and DWI cans?

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3. What are the main applications of OTS cans?

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4. Give three examples of application for general line can.

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5. Mention five important advantages of metal cans for processed food products.

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13.4 ALUMINIUM FOIL

Over the years, aluminium foil has been established as the best flexible packaging material in terms of barrier properties against moisture, gases, light, aroma, etc., as compared to any other material. No other flexible material can match the characteristics of aluminium because foil retains all metallic properties of aluminium.

Aluminium foil is a continuous web/sheet of aluminium metal rolled to thickness/gauges ranging from 0.005 to 0.2 mm. It is produced from commercial purity aluminium having aluminium content of not less than 98 per cent. Foil in hard or soft temper (i.e., annealed), is available with bright or with one side dull/ matt surface. It is available in plain, coloured, coated, lubricated and embossed forms.

I. Properties

The important properties are as follows:

i) Impermeability: Foil of 0.025 mm thickness is impermeable to moisture vapour and gas transmission.

ii) Non toxic: Due to inertness in nature, the foils are completely non-toxic.

iii) Stable: It does not get brittle at low temperature.

iv) Light and heat barriers: It acts as a barrier against light and heat.

v) ***Tasteless and odourless:*** It neither absorbs any odour from food nor releases any off odour to the food.

vi) *Tagger:* It is pilfer proof diaphragm for tin containers.

vii) *Retort pouch:* Foil is used as middle layer in the three layered flexible laminate helps to withstand temperature and pressure in the retort for extending shelf life of ready to eat products.

Advantages

i) Tearing properties facilitates to use the Web as sealing surface in the blister pack.

ii) Impermeable in nature – extensively used for lamination.

II. Applications

i) *Decorative label:* Foil of 0.009 mm thickness can be laminated to paper for flexible label.

ii) *Confectionery:* 0.009 mm thick foil wax backed by paper like glassine, greaseproof or poster is used to pack chocolates, toffee, etc.

iii) *Biscuit wrappers:* Base laminate of 0.009 mm thick foil and 30 gsm poster paper printed in multicolour and wax coated are used as biscuit wrappers.

iv) *Milk products:* Cheese wrappers are composed of 0.012 mm foil coated by heat sealable, anti corrosive coatings.

v) *Multilayer laminates:* Packaging of instant coffee, Pan masala, snack foods, and also for aseptic pouch.

vi) *Stand up pouches:* These are used for packing ready to serve (RTS) beverages.

vii) *Tea chest lining:* Bulk packaging of tea is done.

viii) *Milk strip:* It is used for capping milk bottles.

13.5 PLASTIC MATERIALS

A plastic material is one which is a solid at ordinary temperatures and allows appreciable and permanent change of form without losing its coherence on the application of pressure and heat.

This quality in synthetic or natural materials containing an organic or inorganic compound of high molecular weight is an essential ingredient. The materials are usually solid in finished form but at some stage during manufacture or processing finished articles can be moulded or shaped by flow. The substances of high molecular weight are synthesized from simple chemical components either by condensation or polymerization reactions, yielding products called synthetic resins. The term ‘plastic’ covers a broader group of materials than the term ‘resin’. Usually, heat and pressure together are used to mould or shape the plastic.

Plastic materials are perhaps the most versatile group of materials used in packaging. The use of plastic is fast growing in India due to easy availability of resins. Plastics are light in weight, very strong, hygienic and non-conductive. They do not rust, rot or react with most chemicals.

The development of plastics has resulted into its application in many ways despite its appearance in the market much later as compared to other packaging materials.

The plastic resins are generally categorised as thermoset or thermoplastic resin. Thermoset resins are those materials which can be heated and set to a definite shape but unable to change into another shape by application of heat. The products like electrical switch and other liner materials made of bekelites are covered under this category. Whereas the thermoplastic materials are flexible in nature. These materials can be changed into different types of plastic films with the help of heat application and further, these could be melted and convert into resin form. For example, different types of plastic films used in packaging may be converted into recycled plastic resin materials with the application of heat.

In the current scenario, about one third of all thermoplastic materials manufactured are used in packaging. The plastic materials used for packaging include the polyolefins, principally polyethylene, and polypropylene, poly vinyl chloride (PVC), polystyrene(PS) and polyethylene terephthalate (PET). Out of these about two thirds are used for packaging of food and beverages. Plastics offer distinct advantage over other packaging materials due to its important characteristics like light weight, good mechanical strength, flexibility and recyclability. These materials have excellent barrier properties towards moisture and gases and thus have got wide application in the packaging of food products.

Some of the important thermoplastic materials which have got extensive application in packaging are normally classified into different group based on the polymerisation process and molecular structure like

a) Polyolefins – Polyethylene and Polypropylene (PP)

b) Polyvinyl group – Polyvinyl Chloride (PVC)

c) Condensation polymer – Polyester (PET), Nylon-6 or Polyamide (PA)

d) Styrene polymers – Polystyrene (PS) and Expanded polystyrene (EPS)

e) Carbonate group – Polycarbonate (PC)

a) Polyolefins groups

Depending upon the molecular weight and density, the polyolefins group materials are available in different forms. The important properties of these materials are given below:

i) Low density polyethylene (LDPE) film

- Density ranges from 0.910 – 0.925 gms/cc
- Average molecular weight is 3×10^5
- Resistance to heat (82 – 100°C)
- Translucent type of clarity
- Water absorption is 0.015%
- Permeability to gas is 1.0 cc/m^2/ 24hrs at 27°C and 1 atmospheric pressure
- Good tensile strength properties and high percentage of elongation.
- Good dart impact resistance

- Resistant to weak acids and alkalies
- Good barrier to moisture vapour

ii) Linear low density polyethylene (LLDPE)

- High film tensile strength properties as compared to LDPE
- High percentage of elongation as compared LDPE
- High tear strength properties
- Better stress crack resistance and low temperature brittleness
- Improved stiffness properties
- Excellent puncture resistance
- Excellent heat seal properties

iii) Medium density polyetheylene (MDPE) film

- Density varies from 0.926 – 0.940 gm/cc
- Average molecular weight is 2×10^5
- Resistance to heat (105 – 121°C)
- Translucent type of clarity
- Percentage of water absorption is 0.01
- Permeability to gas is 1.33 cc/m^2/24 hrs at 27^0 and 1 atmospherics pressure
- Very resistant to weak acids, alkalies, etc.
- Effect of sunlight is yellow.

iv) High density polyethylene (HDPE) film

- Density varies from 0.941 – 0.965 gm/cc
- Average molecular weight is 1.25 x 10^5
- Resistance to heat is 121^0C
- Opaque in nature
- High barrier to moisture vapour
- Permeability to gas is less as compared to other polyethylene films
- Effect of sunlight is yellow

v) High molecular high density polyethylene film (HMHDPE)

- High mechanical strength is both directions
- Pleasant white translucence in clarity
- High tear resistance properties.
- Does not impart any taste or odour
- Suitable for food contact application.
- Less elongation as compared to other polyethylene film.
- Excellent moisture barrier properties

vi) Polypropylene (PP) film

- High tensile strength
- High chemical resistance and high temperature performance than HDPE
- Very low permeability to moisture vapour and gas compared to polyethylene
- High transparency
- Chemical inertness
- High softing point

b) Polyvinyl chloride (PVC)

- It is hard, brittle and transparent material

- Low GTR
- Moderate WVTR and good resistance to fat and oil
- Glass like clarity
- Good mechanical strength
- Retention of flavour
- Excellent printability
- Lower weight/ volume ratio
- Resistant to chemicals

c) Condensation polymer

i) Polyester film (PET) film

- It has got excellent gloss
- Very low moisture and gas permeability.
- High mechanical strength
- Resistant to tear, puncture, burst and flex crack
- Dimensionally stable over a wide range of temp. from
- 70C° to + 130°C
- Excellent machinability
- Excellent printability
- Light in weight
- Free from all kinds of additives
- Good surface properties for metallization

ii) Polyamide or Nylon-6 film

- High mechanical strength
- High elongation capability
- Excellent resistance to cutting, perforation, abrasion and bursting
- High chemical resistance to oils and fats
- Outstanding impermeability to gases and vapours
- Easy printability
- Easy metallising
- Economical
- Could be biaxially oriented

d) Styrene polymers

i) Polystyrene (PS)

Polystyrene is not flexible in nature unlike LDPE and PP and is mostly used as rigid containers in the field of packaging. The important features or properties of this polymer are as follows:

- Crystal clarity of containers
- Availability in attractive light or dark colours
- Lustrous finish
- Rigidity and dimensional stability
- Resistant to chemicals
- Easy processing
- Good barrier to moisture.
- Ability to take post moulding decorations like hot stamp foiling, screen printing, inlay foil moulding, etc.

ii) Expanded polystyrene (EPS)

Expanded polystyrene (EPS) is neither flexible nor rigid in nature rather the material is cushing in nature. Normally, the material is called 'thermocole' which has extensive application in the packaging of electronic and light engineering products. In addition, it is also used for the packaging of sea foods. These materials are manufactured in the following forms, i.e., rigid sheets, flexible sheets, granules, cushion moulded and general purpose moulding.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is aluminium foil?

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2. Write the five important properties of aluminium foil.

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3. Indicate four important application of aluminium foil in food packaging.

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4. How do you define plastic material?

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5. What are important groups of polymeric materials used in packaging?

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6. Indicate True or False for the following:

   i) Polypropylene films are more transparent than polyethylene films.

   ii) Polyester films have got more gloss as compared to other plastic films.

   iii) The moisture barrier properties of polyethylene is better than nylon film.

   iv) Polyester film has got better oxygen barrier properties than polyethylene.

   v) Expanded polystyrene has got good cushioning property as compared to polystyrene.

13.6 PLASTIC CONTAINERS

Plastic containers are manufactured with the help of different processes and are available in different forms like bottle, drums, carboys, jars, etc. These have wide application in packaging of processed food products.

The plastic containers are manufactured by means of different processes like:

a) Blow moulding process
b) Extrusion blow moulding process
c) Stretch blow moulding process
d) Injection blow moulding process
e) Coextrusion blow moulding process

13.7 COLLAPSIBLE CONTAINERS

The collapsible containers are mainly available in the form of tube for packaging application. The collapsible tubes are either made from multilayer plastics or aluminium. The aluminium collapsible tubes have been used for long time for the packaging of pharmaceutical products. Now a days, number of products like tooth paste, ayurvedic medicines, cosmetics, stationery, gum, etc., are being packed in collapsible plastic tubes. Due to this innovation, consumers have got alternative packaging materials for the packaging of same products. But it would be necessary for you to understand in detail about both the packaging materials and also applications.

I. Alluminium collapsible tube

The collapsible tube is manufactured by means of extrusion process. However, after extrusion of aluminium slug stampings, tubes remain hard and do not collapse. Tubes are then subjected to annealing process after trimming and threading operation. The annealing is done to impart softness and turning away of greases and other minor extraneous impurities at high temperature. The dimensional accuracy beginning with the slugs punched out from extruded/rolled strips right through the manufacturing process should have a high accuracy with near 'nil' tolerance. Extrusion at a very high pressure, 40 tonnes horizontal or vertical, 'blows' the slug into tube.

After the annealing is over, the tubes are given an enamel coating which is dried for about six minutes in a zig zag conveyor type oven. Then the tubes are printed. Once the tube is ready, it is subjected to capping operation.

Advantages

i) ***Temper proof:*** Cannot be refilled or reused.

ii) ***Protective***: Contents remain well protected and free from contamination.

iii) ***Elegant:*** Attractive, posses a bright surface and lend themselves to trouble free printing.

iv) ***Non-toxic and hygienic:*** Non toxic, non-absorbant and hygienic. Impart no taste, flavour, odour or colour to contents.

v) ***Light weight:*** Reduces transport and handling cost.

vi) ***Complete collapsibility:*** Highly ductile and ensures complete collapsibility.

vii) ***Easy availability:*** Increased production of aluminium has resulted in easy availability of raw material.

*viii)****Economical:*** Unbreakable and easy to use and carry.

Applications

a) *Industrial products:* Adhesives, artist's colour, paints, duplicating inks, lubricants and rubber solutions are packed.

b) *Cosmetics and toiletries:* Cosmetic creams, shampoos, deodorant depilatories, hair cream, hair dyes, shaving cream and tooth paste, are packed.

c) *Food products:* Chutney, condensed milk, honey, mustard cream, tomato ketchup, etc., are packed.

d) *House hold items:* Cream detergents, insecticides and rodenticides, shoe polish, mosquito repellent creams, etc., are packed.

e) *Pharmaceuticals:* Antiseptic cream, pharmaceutical creams, ointments, vaginal jellies, veterinary creams, etc., are packed.

II. Multilayer collapsible plastic tube (Lamitube)

The multilayer collapsible plastic tube, commonly known as 'Lamitube', has been introduced in the Indian market recently and now it has taken a lead in many areas by overtaking the aluminium collapsible tube.

The tubes are produced by extruding a continuous tube by a single or more extruders and then cutting into its required length. The tube shoulder is compression moulded and then welded to the tube in line operation. The tubes are then printed separately in multicoulor graphic. As the tube is seamless and printed individually, the printing is continuous all around the tube. A lacquer coat is given further to protect the surface and provide necessary surface finish.

Applications

- Mainly used for different types of cosmetic products like lotions, cream, spray or liquids.
- In toiletry products like tooth paste, shaving cream, etc.
- Available for industrial products like greases, varnishes and creams used for automobile industry.

13.8 COMPOSITE CONTAINERS

A composite container is a canister or a container made from more than constituent material, generally consisting of paper, boards and kraft papers with metal or plastic ends. It is also called as Combican. A laminated composite container is a container made from kraft papers and boards, laminated with polyethylene or aluminium and heat sealed with the membrane to make it completely leakproof. Because of this unique heat sealing property, the aroma retention capacity of the container increases and permeability of moisture vapour decreases

Applications

i) Food products like custard powder, masala powder, etc.
ii) Detergents and detergent powders.
iii) Pharmaceutical products like tablets.
iv) Pesticides.

I. New Developments

Leak proof composite containers are the new addition where the inner layers are made in such a manner that double seaming of the cans become possible to pack liquid product.

The new developed composite can becomes suitable for the packaging of fruit juice, fruit pulp, preservatives, lube oil, motor oil, tooth powder, talcom powder, etc.

Advantages

i) Acts as an alternate packaging material to tin plate container.

ii) This is disposable packaging and can be used for filling of goods with shelf life of 1-2 years.

iii) Composite container is environment friendly.

iv) The stability of the can for a volume upto one litre is as good as tin or glass containers.

v) Seaming or sealing can be effected on the same line as tin plate containers.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the important processes involved for the manufacturing of plastic containers?

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2. Write five important properties of plastic containers.

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3. What are the important types of collapsible containers?

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4. Mention five important advantages of aluminium collapsible tube.

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5. Explain the important applications of 'Lamitube'.

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6. What do you mean by Composite can?

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7. How many methods are available to manufacture composite cans?

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8. What is the new development in Composite containers?

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9. Write three important applications of Composite can.

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13.9 LET US SUM UP

Packaging is considered to be a need based technology. Depending on the requirement of consumer, the development of packaging is also being occurred. On the one hand, continuous development of food technologies resulted into production of new types of products requiring innovate variety of packaging materials and packages to provide effective barrier properties and adequate strength for longer shelf life. On the other hand, the consumers are demanding for lighter, cheaper, durable and attractive packaging materials or packages. This has compelled to develop variety of packaging materials which could be either rigid, semi rigid or flexible in nature. The packaging materials converted directly into package form to pack the processed food products are termed as primary packaging materials. In addition, certain packaging materials like adhesive, printing ink, etc., are called as ancillary packaging materials.

The packaging materials like glass containers, metal containers, plastic containers, composite containers and collapsible containers used prominently for the packaging of processed food products have been discussed in this chapter. The manufacturing process, types of containers, their properties, application in packaging and important quality measures with respect to each materials have also been described in detail.

There has been tremendous use of flexible plastic packaging materials for the packaging of processed food products in the form of consumer packages. These materials are being preferred by the consumer mainly due to thinner, cheaper and lighter in weight.

Though, there has been lot of criticism by the environmental scientist about the application of flexible plastic materials, but there is a constant growth of consumption of these materials. Due to this fact, the properties of these materials have been covered in this chapter.

You have also learnt about another important packaging material the aluminium foil. Its being flexible in nature and has high barrier properties against moisture, gases, light, aroma, etc., this particular material is extensively used as substrate in the flexible laminate to meet the customers requirement. In short, all the important packaging materials, manufacturing processes, properties and applications have been discussed in this chapter.

13.10 KEY WORDS

WTO : World Trade Organisation

Annealing : Regulated way of cooling of an article to eliminate internal stress and thus breakage.

Throat	:	The channel of the furnace through which the molten glasses are passed away.
Ring pull top	:	A newly designed lid of the can where the lid gets opened up through tearing by puling the ring.
Dead fold characteristic	:	It is the characteristic of soft annealed aluminium foil. While the foil is folded, it remains in folded condition and does not come back.
Grease proof	:	It is the resistance of aluminium foil by which there will not be any seepage of oil or grease on the other side.
GTR	:	Gas Transmission Rate. It is an important property of plastic film.
WVTR	:	Water Vapour Transmission Rate. It is another important property of plastic film.
EVAL	:	Ethylene Vinyl Alcohol. It is another polymer.
LCC	:	Leak proof Composite Container. Enables to make double seaming so that liquid products can be packed.
UV curing	:	The drying of printed surface under ultra violet light which improves scuffproofness property.
Tensile strength	:	The strength or force by which the polymeric material breaks while under tension.
Parasite	:	The thermoplastic material when extruded in the form of pipe under blow moulding process is called as parasites.
Billets	:	Billets are the rectangular blocks of caste metal, used for the manufacturing of aluminium foil.

13.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answers should include the following points:

1. i) Wood is the oldest packaging material appeared in the beginning of 1950 for the packaging of heavy engineering and electronic products.

   ii) Jute fibre is considered to be the second appearance as natural packaging material. The material has got tremendous application in packaging of food grains.

iii) Glass containers have appeared in the market as packaging material especially for the packaging of pharmaceuticals, alcoholic beverages, etc.

- Plastics materials have entered in bigway during the period of mid fifties and early 1960's. Initially, polyethylene and PVC have shown the application in packaging.
- In the late 1970's and early 1980's, plastic carry bags have been introduced in the Indian market. Subsequently, these materials have taken a lead over other materials for the packaging application.

2. a) Wooden containers
   b) Plastics
   c) Jute

Check Your Progress Exercise 2

Your answers should include the following points:

1. - The main constituents are sand, lime stone and soda ash.
   - Other ingredients like arsenic, sclenium and cobaloxides are added to make clear glasses.
   - Boron is added to make it stronger.
   - Carbon and sulphides are added to make amber (brown) coloured glass.

2. - Inertness, non permeable, transparent, mouldable
   - Impact strength, light weight and unlimited supply

3. - Used for all types of product packaging
   - High temperature resistance
   - Can be made in any size, shape and capacity
   - Impermeable to moisture and gases
   - Can be made in different colour depending upon the requirement

Check Your Progress Exercise 3

Your answers should include the following points:

1. - General line can
   - OTS can

2. - Open top sanitary (OTS) cans are three piece cans where as Drawn and Wall Iron (DWI) cans are tow piece cans.
   - Open top sanitary cans are mainly used for processed food but the other one is confined to the application of pressurised beer and beverages.

3. - Processed food
   - Edible oil
   - Coffee, baby food and chocolate
   - Paints, insecticides and pesticides

4. • Hydrogenated fat or vanaspati
   • Bakery products
   • Confectionery items

5. • Can be fabricated readily
   • Imperable to light, gases and moisture
   • Non-toxic
   • Amenable to heat sterlization
   • Amenable to printing

Check Your Progress Exercise 4

Your answers should include the following points:

1. A continuous sheet of aluminium metal rolled to thickness ranging from 0.005 to 0.2 mm.

2. Impermable, non toxic, light and heat barriers, tearability, moisture and gas barrier.

3. • Lidding foil, biscuit wrapper.
   • Decorative label, tagger and an important substrate of flexible laminate

4. • A plastic material is a solid at ordinary temperature and allows appreciable and permanent change of form without losing its coleurence on the application of pressure and heat.

5. • Polyolefin group
   • Polyvinyl group
   • Condusation polymer
   • Styrene polymers
   • Carbonate group

6. i) True ii) True iii) True
   iv)True v) True

Check Your Progress Exercise 5

Your answers should include the following points:

1. • Injection blow moulding
   • Co-extrusion blow moulding
   • Extrusion blow moulding
   • Stretch blow moulding

2. • Can be made in any size, shape and capacity
   • Good impact resistance
   • Low permeability to gases and moisture vapour
   • Customer friendly due to innovative opening device
   • Smooth finish surface enhance eye appeal

3. • Aluminium collapsible tube
   • Lami tube

4. • Tamperproof

- Non-toxic and hygienic
- Elegant
- Economical
- Light weight

5. - Cosmetic products
   - Toiletries products
   - Industrial products like greases

6. A can made of dissimilar material where the body is made from paper and the ends are made either from plastic or metal.

7. - Convolute
   - Spiral winding
   - Lap seal method

8. Leak proof composite can which could be used for packaging of liquid products like fruit juice, tube oil etc.

9. - Detergent powder
   - Pesticides
   - Pharmaceuticals products

13.12 SOME USEFUL BOOKS

1. Packaging Technology Education Volumes (Part 1) (2001) Indian Institute of Packaging, E-2, M.I.D.C. Area, Chakala, Andheri (East), Mumbai.
2. Brody Aaron, L. and Marsh Kenneth, S. (1986) The Wiley Encyclopaedia of Packaging Technology.
3. Plastics in Packaging (1986) Indian Institute of Packaging, E-2, M.I.D.C. Area, Chakala, Andheri (East), Mumbai.
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UNIT 14 PACKAGING PROCESS AND MACHINERY

Structure

14.0 OBJECTIVES

After reading this unit, you should be able to:

- describe about the packaging systems for the transportation of fresh or chilled fruits and vegetables;
- explain the mechanism of various packaging systems for processed food products;
- discuss about the manufacturing processes of different packaging materials; and
- define the machinery, techniques and processes used for packaging processed food products.

14.1 INTRODUCTION

In India, the processed food industry requires primarily the technology in three areas. These are food preparation, packaging and techniques that allow the extension of shelf life of food products. Moreover, the constant research work in the field of food technology has made it possible to develop newer products which require different packagings. At the same time, there has been continuous effort by the industries as well as Government to promote the exports of processed food products. Exportable products require different packagings in terms of durability, higher strength properties, attractiveness and also shelf life.

In order to meet the requirement of export market, there has been enormous development of packaging technology in terms of newer materials, systems and machinery. These developments have not only made it possible to compete with the International brand but also made a position on the shelf of super markets.

Moreover, the newer system of packagings have made the products available throughout the year by enhancing the shelf life. At the same time, there has been enormous development in the packaging machinery also. The newer types of packaging machinery accelerated the productivity with high accuracy and low wastage.

On the other hand, the conversion technology of packaging materials resulted in the availability of various options for processing technology. This technology enabled to manufacture newer types of packaging materials having high barrier properties in order to improve the shelf life of processed foods and higher impact strength to withstand shock and vibrations during handling, storage and transportation. This conversion processes also enhance the productivity with low energy inputs and reduce the cost of packaging materials.

However, there is a constant need to upgrade the existing processing machinery by way of incorporating newer techniques and systems so that the Indian food products and packages could become globally competitive.

14.2 PACKAGING OF FRESH/CHILLED FRUITS AND VEGETABLES

Fresh or chilled (at 4^0C temperature) fruits and vegetables are basically living tissues, high in water content and diverse in terms of morphology, composition and physiology. The package design depends on the requirement of the produce within the frame work of handling and marketing system. The main causes of deterioration in fresh produce are metabolic changes, mechanical injury and attack by pests and diseases. Though, there are variety of packages but there is no rigid rule that a particular material or style is to be followed for a particular type of fruits and vegetables.

I. Product characteristics of fresh produce

i) Highly perishable in nature and are very easily affected by the climatic conditions, distribution hazards and microbial decay.

ii) Respiration process of fresh produce releases oxygen and carbon dioxide. Rapid respiration results in fast ripening or aging of the produce.

iii) Loss in moisture of fresh fruits and vegetables during storage and transportation resulting into drying causing wilting, shrivelling and loss of rigidity. In addition, there will also be loss in weight.

iv) Appearance of microorganisms like bacteria and mould.

v) Very low temperature causes chilling injury which damages the delicate tissues of fresh produce and thus restrict the shelf life.

vi) Changes in colour, texture, odour and flavours.

II. Requirement of package design

a) Pre-cooling

Pre-cooling of fresh fruits and vegetables after harvesting is required to slow down the enzymatic and respiratory activity, minimize susceptibility to micro organisms and to reduce water loss and ethylene production. Pre-cooling helps in removing the field heat prior to storage. The different methods of pre cooling are forced air cooling, vacuum cooling and hydro cooling.

b) Ventilation

The package should be provided with proper ventilation holes during transportation. Cold air is constantly circulated through the container to remove the heat transmitted during the cooling process.

c) Mechanical damage

The package should have adequate impact strength to withstand the shock and vibration which occur during handling, storage and transportation resulting into mechanical injury of fruits and vegetables. In addition, the fresh or chilled produce will have bruising affect during transit due to vibration.

III. Packaging materials

The packages for fresh fruits and vegetables can be classified as:

A) Consumer/ Retail packs

B) Transport/ Bulk packs

A) Consumer or retail package

Consumer packages are small in size designed to hold half dozen or one dozen fruit or ½ kg to 1 kg vegetables. There are many types of consumer packs used for the packaging of fresh fruits and vegetables. The selection for the type of consumer pack depends on marketing characteristics of the product. The most commonly used packages are listed below:

i) Flexible plastic film: Plastic pouches made of LDPE, PVC or PP are used for the packaging of horticultural produce.

ii) Trays with overwrap: The trays used are usually made of moulded pulp tray or thermoformed plastic materials like EPS, PVC and PP. The produce is placed in individual cavities so that abrasion and brushing is avoided. Transparent LLDPE based cling films are used to wrap the trays. The films are semi permeable and allow exchange of gases for respiration of the product.

iii) Plastic punnets: Punnets made from either PET or PVC are food grade, odourless and light in weight. These are also amenable to stacking during storage.

iv) Plastic net bag: The plastic net bags have feature to stretch and accommodate all sizes and shapes of produces. These nets are generally made of HDPE or PA (Polyamide).

v) Foam sleeve: This is a tubular film made of polyethylene foam available in different colours, diameters and lengths. It is hygienic, non-toxic and odourless. This could be easily slipped over the individual fruit in a snug fit form.

vi) Shrink wrap: This is one of the latest trend to shrink wrap the individual produce. This pack restricts the moisture loss. In addition, it provides see through property. The films most commonly used are LDPE or LLDPE.

B) Transport packs

The normal size of transport package is between 15 to 20 kg which is suitable to carry by hand. Transport packages can be broadly classified as follows:

(a) Rigid containers:

i) *Bamboo basket:* Bamboo baskets are widely used even today as transport pack for domestic market. These are available in various shapes, sizes and designs but they do not have the rigidity and stackability during long distance transport.

ii) *Wooden box or container:* The conventional baskets are replaced by wooden box. However, the use of wooden boxes are discouraged now a days as they directly promote deforestation.

iii) *Plastic crates:* Crates made of HDPE or PP have got high impact strength. In addition, these are reusable, amendable to withstand journey by different mode of transportation and also provide good stackability during storage and transportation.

iv) *Solid fibre board:* These materials have got very limited application.

v) *Corrugated fibre board boxes:* The boxes are widely used as shipping containers for fresh produce because of numerous advantages over wooden boxes.

vi) *Plastic corrugated box:* These are usually made of HDPE or PP. HDPF have got light impact strength and low degradation by Ultra Violet radiation while polypropylene has a better scratch resistance.

(b) Flexible containers:

Sacks made of either plastic, jute or paper could be used for the packaging of horticultural produce. This facilitates breathing of fresh produce and have also got high stackability during storage and transportation.

IV. New trend

Modified atmosphere packaging (MAP) is a system involving the removal of air from the packages and replacing with a single or mixture of gases. The gas mixture used depends on the type of the produce.

The MAP system is a dynamic one where respiration and permeation occur simultaneously. Factors affecting both of these must be considered when designing a package. The selection of a film or combination of more than one film (laminates) depends on the expected transpiration and respiration rate of the produce.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the important characteristics of fresh fruits and vegetables?

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2. What are the different packaging options for fresh fruits and vegetables?

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3. Explain the new trend of packaging for the enhancement of shelf life for fresh fruits and vegetables.

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14.3 PACKAGING OF FROZEN FOODS

Freezing is considered to be one of the most important technique for the preservation of food products. This technique is mostly employed for the preservation of fresh fruits and vegetables. At low temperature, both microbial growth rate and metabolic activity of foods are reduced by a factor of 1/2 to 1/3 for each 10°C drop in temperature.

Frozen fruits and vegetables should be stored nearly at –16°C to maintain the superior quality. Storing frozen foods at temperatures higher than –16°C increases the rate of deterioration and reduces their shelf life. Fruits and vegetables of high quality and good nutritional value can be achieved under frozen conditions. However, these are primarily based on the following aspects.

a) Physical and chemical changes which take place during freezing process

b) The effect of freezing on fruit and vegetable tissues

c) Food spoilage microbiology

I. Critical factors of frozen food

During freezing operation fruits and vegetables undergo certain physical and chemical changes which affect their quality. Under physical changes, the following critical aspects are to be considered.

i) Moisture is lost as ice crystals evaporate from the surface of the product, producing freeze burn – a grainy, brownish spot where the tissues become dry and tough.

ii) This freeze-dried surface area is prone to development of off flavour.

iii) Freezing of fruits and vegetables consequences into freezing of water resulting into rupturing of cell walls. The texture of the produce, when thawed, becomes much softer as compared to raw produce. This kind of physical change is generally found in vegetables like tomato, which become mushy and watery. However, this type of change is less noticeable in high starch vegetables such as peas, corn and beans.

Similarly, some chemical changes also occur in fresh fruits and vegetables during freezing. The important critical factors to be considered are:

i) Development of brown colour and loss of vitamin C due to enzymatic reactions. In order to prevent this reaction, there is a need to inactivate the enzymes by blanching. This process also helps in destroying the microorganisms present on the surface of fruits and vegetables.

ii) The development of rancid oxidative flavours is another chemical change that takes place through contact of the frozen product with air.

Most of frozen fruits maintain high quality for 8 to 12 months. Unsweetened fruits lose quality faster than those packed in sugar syrup as sugar itself acts as a preservative. Similarly, most of frozen vegetables maintain a high quality for 12 to 18 months at –16°C or lower. Longer storage of frozen fruits and vegetables may not be unfit for consumption but the quality of produce is reduced drastically.

II. Requirement of packaging

Considering the critical factors responsible for the physical and chemical changes of produce that occur due to freezing, the packaging materials should have the following properties to meet the requirement.

i) The packaging materials should have high moisture barrier property so that the material could be used as wrapper to prevent “freeze burn”.

ii) Frozen foods also require the packaging material with high oxygen barrier property so that the products could be wrapped to prevent the development of oxidative rancid flavour.

iii) The packaging materials should have light barrier property so that the effect of UV light in the oxidative reaction could be minimised.

iv) The material should have good printability and heat seal property.

v) The packaging materials should also have low temperature resistance so that wrapped product could be freezed at low temperature without having any crackness on the materials.

III. Types of packaging materials and packages

Frozen fruits and vegetables are normally subjected to blanching or sealing process to destroy the enzymes. Subsequently, they are packed prior to freezing operation. In general, there are two types of packages namely dry pack and tray pack.

a) *Dry pack*

This is the method used to pack the blanched and drained vegetables into containers or freezer bags. The vegetables like broccoli, pack tightly in the freezer bag by arranging the heads and stems in alternate manner so that there should not be any air inside the bag. This kind of bag is normally made from either low density polyethylene (LDPE) or PVDC coated plastic film, 3 layered laminate structures with PET/Al-foil/Polyethylene or five layered coextruded multilayered plastic film (PE/Tie/ Nylon/ Tie/ PE). These type of packaging materials have high impact strength, low temperature resistance and moisture barrier. These packages can be subjected to freezing at a temperature of –16°C or below.

b) *Tray pack*

This type of packages, where the trays are made of collapsible corrugated fibre board, are made from either 3 ply or 5 ply. However, top layer of the board is coated with plastic film to provide water proof property. This kind of board is converted into tuck-n-type tray by means of die-cut machine. However, one single layer LDPE film is spread on the tray so that the produce may not have direct contact on the inner surface of the board. The blanched and drained vegetables are then placed on the tray. As an alternative, the plastic bag filled with blanched and drained vegetables can further be packed into collapsible tray.

IV. Properties of packs

i) Tray pack can be more attractive by way printing on the surface as compared to dry pack.

ii) While freezing, tray pack may not be deformed as the package will have adequate strength. But there is a possibility of deformation or appearance of wrinkles on the products during freezing.

iii) Dry packs are cheep as they are made from either single or multilayered flexible packaging materials.

iv) Dry pack made of plastic bag should have good heat seal property whereas the tray pack should have high compression strength.

v) In both the cases, the selection of flexible packaging material is very important as the materials should have low temperature resistance.

V. New developments

i) *Aluminium tray*

Tray can be made from aluminium sheet instead of paper board. This type of package can be stored at even –40°C without any damage to the tray. Moreover, the oxygen barrier property is excellent and prevention of freezer burn is good.

ii) *Plastic tray*

Plastic tray made of HDPE is extremely used as transport package for the storage of fruits during freezing. However, the individual fruit is washed properly, packed in plastic bag with sugar syrup, heat sealed and then stored in plastic tray for freezing.

VI. Application

The following fruits and vegetables are normally available in frozen form.

A) Fruits **:** Apples, apricots, peaches, straw berries, pine apples, citrus fruits, etc.

B) Vegetables **:** Beans, carrots, cauliflower, peas, potatoes, pumpkin, spinach and other green vegetables.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What changes could occur during freezing of fruits and vegetables?

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2. Write down the important critical factors to be considered for frozen foods.

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3. Discuss the important requirements of packaging of frozen foods.

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4. Mention two most important types of packages used for frozen foods.

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14.4 PACKAGING OF DEHYDRATED FRUITS AND VEGETABLES

Dehydration of fruits and vegetables or removal of water from fruits and vegetables is the simplest techniques of food preservation. There are number of products which are available in the dehydrated form, for example raisin, mushrooms, apples etc.

The drying process has to be controlled so as to avoid common problems such as tissue shrinkage, browing and heat damage, case harding, loss of rehydrability or solubility and loss of flavour volatiles. Many a times, the dehydrated product is subjected to agglomeration or instantanization for better solubility and quality.

I. Product characteristics

i) Highly moisture sensitive and tends to absorb moisture resulting into stickiness.

ii) Changes in colour, texture and odour during storage.

iii) Susceptible to microbial spoilage due to the appearance of fungal growth on the surface.

iv) Certain products are oxygen sensitive resulting into rancidity which affects the taste of products.

II. Packaging requirement

i) Air tight package

The package could be made of high moisture barrier plastic films like coextruded plastic film, polyester/ polyethylene laminate, etc. The package should be air tight in the form of either pillow pouch, made in FFS machine, or 3 sides sealed pouch.

ii) Plastic containers

The plastic containers made of either PET blow moulded HDPE could be used.

iii) Vacuum package

The dehydrated fruits and vegetables could be packed in plastic pillow pouch and then subjected to vacuumisation. The vacuum pack will help to avoid oxidation rancidity and also protect the product from moisture absorption. Thus, the shelf life of product will be enhanced. The plastic pouch could be made either from laminate made of aluminium foil/polyethylene or polyester/ polyethylene.

iv) Gas package

To enhance the shelf life a product can be packed by creating a vacuum and flushing with inert gas in a container. As an alternative, laminated plastic pouch could be vaccumised, gas flushed and sealed in automatic FFS machine.

v) Pouch in box

The vacuum pouch of dehydrated products could further be packed into composite can and sealed at top to make it air tight. In some cases, the vacuum pouch could to be packed in either carton made from duplex board or 3 ply microflutted (E flute) corrugated fibre board box.

14.5 MANUFACTURING OF PACKAGING MATERIALS

14.5.1 Glass Containers

I. Composition

The main constituent of glass are sand, lime stone and soda ash. The sand used is known as silica or glass sand. Silica sand is melted at the first stage of making glass where soda ash helps it to melt with greater ease. Glass made with the glass sand and soda only is partly soluble in water. When crushed lime stone is added, the resistance of glass to water increases greatly. There are few other chemicals that are added to these three main ingredients to make the glass container stronger and cleaner or coloured as may be required.

In some cases, arsenic, selenium and cobalt oxides in proper proportion are added to make clear glass. The green or brownish shade in glass comes from the impurities in natural sand, mainly iron.

Boron from borax is added to glass to make the container stronger and to increase its resistance to acids. This chemical also reduces the thermal expansion of the glass.

Colours are added to glass by adding small quantities of chromium, cobalt, iron and other colourants depending on the colour required.

For amber (brown) glass, carbon and sulphide are added. Depending upon the qualities and the colour, raw materials are mixed in requisite proportions.

II. Manufacturing process

Depending upon the requirement of type and colour of glass containers to be manufactured, the raw materials are weighed, mixed thoroughly and fed into a glass melting furnace by maintaining a temperature of about 2700°F (1560°C). The melted glass is then passed into the refining chamber of the furnace. Impurities are retained in the melting chamber and the purified glasses are passed through a channel in the furnace called “Throat”. The molten glass passing through the ‘throat’, enters into the refining zone of the furnace where some bubbles, normally escaped through the throat, are allowed to be fined or eliminated and then it enters to the gob feeder. At the precise position, just above the forming machine, the glass is allowed to leave the furnace through a cylindrical hole in the bottom of the feeder and the stream of glass is cut off to a predetermined diameter and length of shears to form a gob. The gob falls into a blank mould, usually made of cast iron, to be shaped into a parison or semifinished container. It is then transferred into a second mould, called finished mould, whose internal cavity is accurately machined to correspond to the desired external shape of the container. The glass container as it emerges from the finished mould has a temperature about 800°C but it cools and hardens quickly. It is then immediately transferred to a tunnel like annealing with planned heating zones to cool slowly. This gradual and regulated cooling of the container eliminates the internal stresses and as it emerges from the other end of the lehr. Then the glass containers are inspected for any faults or defects before packed into corrugated fibre board boxes for the despatch to the user industries.

14.5.2 Metal Cans/Open Top Cans

The tin plate is purchased in the form of sheets either locally or imported. Depending up on the requirement the thickness of tinplate used varies from 0.006” to 0.012”. The following steps are used for the decoration and the manufacturing of tin plate (Figure 14.1).

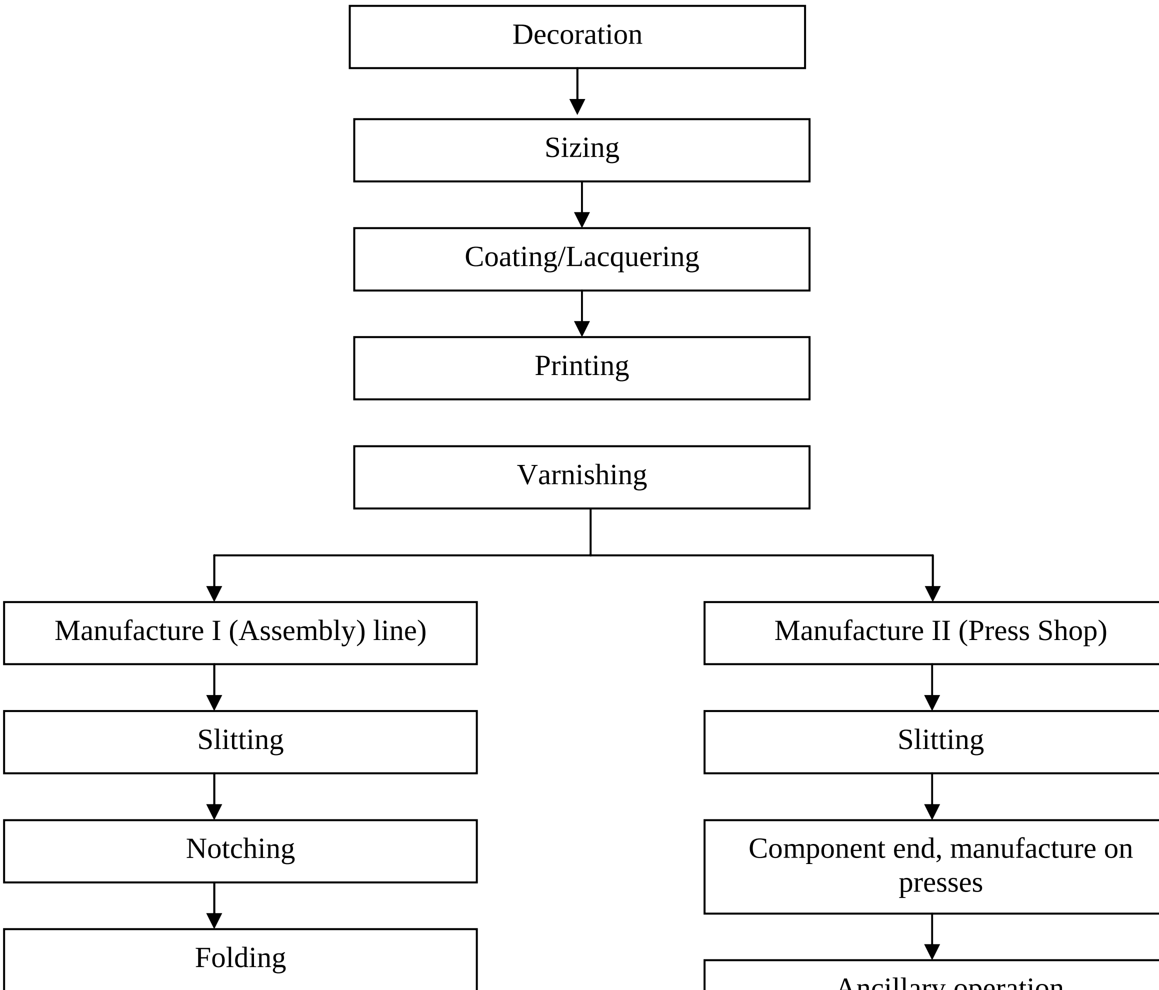

Figure 14.1: Flow diagram of decorated tin plate manufacturing

Though, the plastic containers are constantly replacing tin plate containers in many areas, even though, tin plate containers are continued to be an ideal packaging material for processed food due to the following advantages:

i) They are strong enough to protect the contents during handling and transportation.

ii) The materials are light enough for commercial handling.

iii) They can be readily fabricated into desired sizes.

iv) They are impervious to air and water.

v) They are capable of being heated for sterilization. These containers can with stand the internal pressures during processing of the food.

vi) The materials are not harmful or toxic to their contents.

vii) They can be easily printed for good market appeal.

viii) They can be manufactured at very high speed.

ix) The processed food has got maximum shelf life of 12 months in tin plate containers as compared to any other packaging material.

14.5.3 Plastic Materials

A) Plastic rigid container

Different manufacturing processes are involved in the production of plastic containers by using thermoplastic materials.

a) Blow moulding process

In this process, the thermoplastic materials are extruded in the form of pipe (it is called as parasite) through an annular die (directed downwards) and then blowing it inside the cavity of a closed mould with the help of compressed air to assume the shape of the cavity. Depending on the die, the plastic containers of different capacities, sizes and shapes are manufactured. This method has got most of the major advantages over extrusion and injection techniques and is used to produce thermoplastic hollow ware like bottles.

b) Extrusion blow moulding

Basic parts of this machine are the extruder, die head, mould, clamping unit, blow pin and new blowing unit and control system.

At the first stage, extrusion of the parison is accomplished with a heated, hollow barrel in which a rotating screw conveys solid feed material, compresses and melts it and finally pumps the melt through a tubing die to form the parison. The actual shape and design of the screw is dependent on the theological properties of the plastic materials. Hence, for different types of polymers, different screws are used.

After the plastic has been melted at a low temperature to maintain high melt strength the vertically extruded tube supports itself and then the plastic melt is fed into an extrusion head. For polyethylene, die head with programmable mandrels can be used.

c) ***Stretch blow moulding process***

This method differs from the conventional blow moulding. In that the parison is "Biaxially Oriented" to impart much superior mechanical properties to the blow moulding containers. This process has the following sequence:

- Formation of a parison by injection moulding or by extrusion
- Longitudinal stretching of the parison
- Radial orientation while blowing the parison into the mould
- Ejection

This process can be continuous or in two stages. In the 2-stage process, perform is moulded first and then subsequently reheated, stretched and blown in a secondary operation. Mineral water bottles made of PET are manufactured by using this technique.

d) ***Injection blow moulding***

It is almost same as stretch blow moulding. A parison is injection moulded over a core pin and the threaded neck is formed. The core pin can be shaped so that the plastic can be thin and thick at different points to produce an acceptable bottle. The injection-moulded perform is then transferred to a blow station where the core pin opens and allows air to blow a bottle into the shape of the blow mould. This method is quite popular in advanced countries for moulding small bottles up to 250 ml capacity. In India, injection blow moulding method is yet to be used.

e) ***Co-extrusion blow moulding***

This method can only be accomplished through the multilayer combination of resins to produce co-extruded bottles. This system includes additional extruders and head system where the plastic is brought in at different points and layered to form a parison and follow the same process of blow moulding technique.

The polymeric materials like polystyrene (PS), high density polyethylene (HDPE), polypropylene (PP), polycarbonate (PC), etc., are normally used to manufacture the rigid containers by using the injection blow moulding process.

f) ***Compression moulding***

The science of compression moulding, particularly thermosetting plastics and rubber, is well established. The use of this technique is very rare for processing thermoplastics because of longer moulding cycles involved. In principle, this technique involves the following steps

i) Filling the heated female mould cavity with the moulding powder.
ii) Pressing the powder with the male mould into shape after a breathing stroke.

iii) Maintaining the desired temperature and pressure over a length of time.
iv) Cooling the mould to a minimum possible temperature.
v) Ejection of the article.

B) Plastic films

The thermoplastic polymeric materials are also used to make the flexible plastic films having thickness from 8 to 250 microns. Plastic films are manufactured mainly by two methods, i.e. blown film co extrusion process and cast film co extrusion process.

In case of blown film coextrusion process, the extrusion machine used with either 3 or 5 extruders. However, single extruder machine can also be used to make plastic film by using blown techniques. In this process, polymeric material of single or multiple type is blended and fed into separate hopper, subjected to melt with separate melt channels and then passed through one die that is bonded to form single web of multilayer co extruded plastic film. Now a days, blown film coextrusion process has become very popular as this technique provides plastic films higher impact strength, barrier properties and high seal strength.

In cast film co-extrusion process, the individual layers are combined in multilayer adapters and distributed across the width of a cast film die. Now a days, multilayer co-extruded plastic sheets are being produced by using this technique. This kind of cast plastic sheet has got wide application in manufacturing of thermoformed containers, used extensively for the packaging of processed food products.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are the constituents of glass?

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2. Indicate the steps followed for the manufacturing of glass.

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3. What are the important steps followed for the manufacturing of metal containers?

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4. What is called parasite in blow moulding process of plastics? What are the sequences in the stretch blow moulding process?

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14.6 ASEPTIC PACKAGING

Aseptic packaging can be defined as a procedure consisting of sterilization of the packaging materials or container, filling of a commercially sterile product in a sterile environment and producing containers which are hermetically sealed so that recontamination or reinfection is prevented. This results in a product which is shelf stable under ambient conditions. The term 'aseptic' is derived from the Greek word 'Septices' and implies the absence or exclusion of any unwanted organisms from the product, package or other specific areas. The term 'hermetic' is used to indicate suitable mechanical properties to prevent the passage of microorganisms and gas or vapour into or from the container.

I. Steps followed in aseptic system

Aseptic processing comprises the following:

a) Sterilization of the product before filling

b) Sterilization of the packaging material or container before filling operation

c) Filling the product into the sterile package by maintaining the aseptic condition

a) Sterilization of product

The product sterilization is carried out by in-process or on-line sterilization which is popularly known as the ultra high temperature (UHT) or high temperature short time (HTST) depending upon the product treatment. The essential difference between the sterilization through autoclave, i.e., conventional canning method, and on-line UHT treatment is that in canning, the sterilization is done after the product is packed, whereas in UHT method, the sterilization is done prior to packaging. Normally, the sterilization temperature is maintained at 133–135°C for 3 to 5 seconds under HTST/UHT method to make the product sterile. However, there may be slight variation in temperature and duration depending on the type of product.

b) Sterilzation of packaging materials and equipment

Different kind of sterilizing agents like heat, chemicals and radiation are used alone or in combination for sterilization of aseptic equipment and packaging materials.

i) Heat

Initially, product supply lines and fillers are commonly sterilized by moist heat in the form of hot water or saturated stream under pressure. 'Dry heat' in the form of superheated steam or hot air may also be used to sterilize equipment. However, due to the relatively high dry heat resistance of bacterial endospores, the time-temperature requirements for dry heat sterilization is high. Systems enjoying moist heat are frequently sterilized at temperatures ranging from 121–129°C, while 176–232°C is used for sterilization by dry heat.

ii) Hydrogen peroxide

Hydrogen peroxide (H_2O_2) is not an efficient sporicide when used at room temperature. Therefore, most aseptic packaging systems use H_2O_2 (at concentrations of 30 to 50%) as a sterilant for packaging materials followed by hot air (60–125°C) to dissipate residual hydrogen peroxide.

Other chemicals which have been used as sterilents for acid foods include various acids, ethanol, ethylene oxide and peracetic acid.

iii) Radiation

A dose of approximately 1.5 megaradians (MGRAD) Gamma radiation is commonly used to decontaminate containers for acid and acidified foods. Doses required to sterilize containers for use with low acid foods are considerably higher than those required for acid and acidified foods.

Ultraviolet (UV-C) light has been used to decontaminate food contact surfaces. The low penetration and problems associated with shadowing limit the use of UV-C for aseptic systems packaging of low acid foods.

c) Filling of the product under aseptic condition

Once the product has been brought to the sterilization temperature, it flows into holding tube. The tube provides the required residence time at the sterilization temperature. No external heating of holding tube should take place.

A deaerator is used to remove air from the product processed and packed aseptically. The deaerator generally consists of a vessel in which the product is exposed to a vacuum on a continuous flow.

The sterilized product is accumulated in an aseptic surge tank prior to packaging. The product is pumped into the surge tank and is removed by maintaining a positive pressure in the tank with sterile air or other sterile gas.

Aseptic packaging system has been introduced in India by Tetrapack Company and marketing the different process food in tetra packs. The most commonly system is followed by Tetra pack, called as Tetra classic aseptic (TCA) system. The packages produced have a tetra hedronal shape. The ratio of packaging material to packaged product is a very favourable one, i.e., the amount of packaging material needed to package the volume of food is small.

Similarly, the TBA/3 (Tetrabrik Aseptic) system was introduced into the Indian market in the beginning of 1970. The containers produced are ‘brick shaped’ and easier and more efficient to handle during storage and distribution.

The tetrabrik packages are brik like shape and made of six layers of packaging materials. Composition of Tetrapack Aseptic carton is given below (Figure 14.2). The 6 layers in the brick provide total protection to the packaged product.

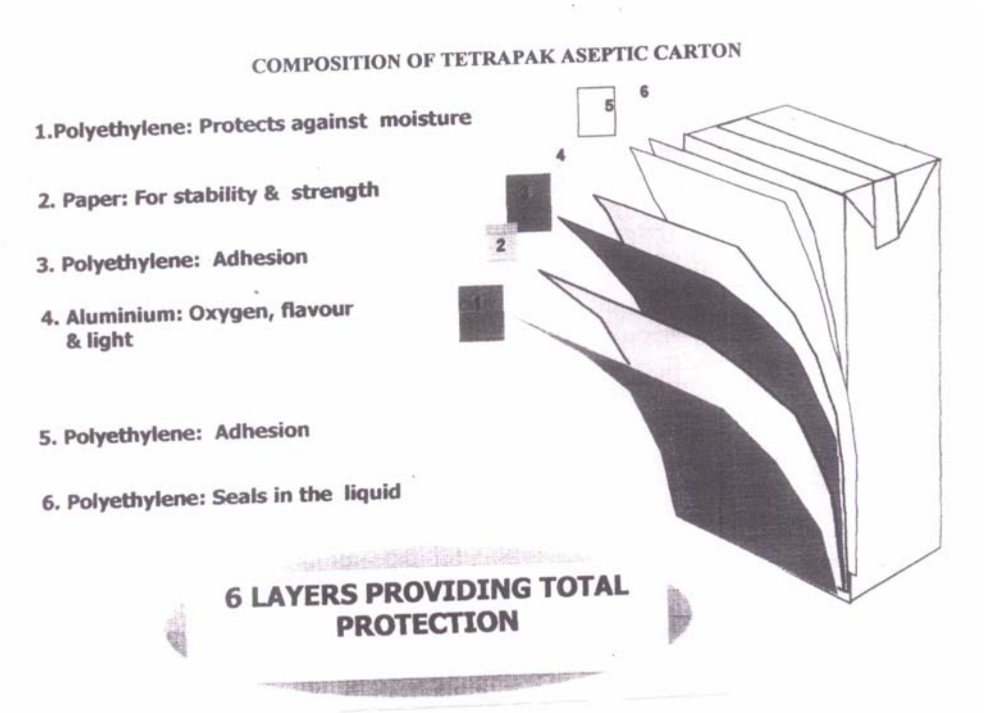

Figure 14.2: Composition of tetrapack aseptic carton

A number of processed food products which are liquid or semi solid in nature, are available in the aseptic packages. The common products aspeticall packed are fresh milk and flavoured milk, fruit juices, yougurt, vegetable oil, chocolate milk, Milk curd, cream.

II. Types of aseptic packages

A variety of consumer packages may be filled aseptically as listed below:

i) Carton box

ii) Bags and pouches

iii) Cups and Trays – Polypropylene based multilayered materials with EVOH barrier materials are used.

iv) Glass bottles and Jars

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define aseptic packaging system?

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2. What are the steps followed in this technique?

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3. How do you sterilize the product under this process?

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4. Describe the different sterilizing agents for packaging materials.

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5. Give examples of types of aseptic packaging.

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6. What are the applications of this technique?

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14.7 VACUUM AND INERT GAS PACKAGING

Vacuum packaging is the simplest and common method of modifying the internal gaseous atmosphere in a pack. The food product is placed in a pack made of a plastic film or laminate of low oxygen permeability. Air is then evacuated and the package is sealed. An evacuated package collapse around the product so that pressure inside is much less than atmosphere.

Similarly, the gas and vacuum package is dealt with the removal of air from the pack and the vacuum space is replaced by a single gas or mixture of gases. The gas mixture used is dependent on the type of product.

I. Vacuum packaging

In this process a vacuum is applied to remove the air from a preformed flexible pouche, containing the processed food product and then sealing it. The plastic film used should have low oxygen permeability under good vacuum condition, the oxygen level is reduced to less than 1%.

The main significance behind this technique is to extend the shelf life of processed food product. The processed foods having high content of fat like deep fried potato or banana chips, namkeen, bhujia, roasted peanut, roasted ground nut, etc., become rancid due to reaction with oxygen present in container. Due to this fatty foods become bitter in taste and unacceptable to the consumers.

In order to preserve these products, there is a need to evacuate the air from inside the package. However, this technique is most suitable for the products which are powder in from like tea, skimmed milk powder, etc. But this technique is not suitable for granular or flaked or bakery products as the products get crushed due to evacuation of air from the package.

II. Gas packaging

Gas packaging can be achieved by two fundamental methods. One is the replacement of air with a gas or a mixture of gases mechanically. The other is by generating the atmosphere within the package either passively, as in the case of fruits and vegetables, or actively by using suitable atmosphere modifiers such as oxygen absorbents, carbondioxide absorbents or emitters. In general, gas flushing process is usually performed on a form-fill-seal machine. Gas is injected into the package to replace the air. This dilutes the air in the head space surrounding the food product. When most of the air has been replaced, the package is sealed. There is a limit to the efficiency of the system since replacement of air in the package is accomplished by dilution. Typical residual oxygen levels in gas flushed packs are 2-5% oxygen. Inert gas like nitrogen is also used to flush the packages.

In case of fresh fruits and vegetables, the atmosphere inside the package is modified passively. Fruits and vegetables continue to respire even after harvest. That means, the produce consumes oxygen and produce carbon dioxide and water vapour. If the respiration characteristics of the commodity can be accurately matched to the permeability of the film used for packaging, then a favourable modified atmosphere can be created passively within the package and an equilibrium concentration of oxygen and carbondioxide is established. Equilibrium modified atmosphere (EMA) containing 2.5 per cent oxygen and 3.8 per cent carbon dioxide could delay the maturation process and softening of the vegetables, reduces chlorophyll degradation, microbial spoilage and enzymatic browning.

Under active packaging, the package containing food products where certain additives are incorporated either in the packaging film or within packaging container to modify the head space atmosphere. Different additives are added to the package to act as oxygen absorbant, carbon dioxide absorbant or scavenger, ethylene absorbant and ethanol vapour generator, etc. This is relatively a new technology and presently quite expensive.

14.8 FORM-FILL AND SEAL EQUIPMENT

Over the years, the form-fill-seal machine has gained popularity and acceptance for packaging of commodities. This particular equipment is suitable for flexible packaging materials and as well as semi rigid packaging materials. The machine operates with either one or two ebs of films which are transported vertically and horizontally. This machine helps to form a package from packaging material and allows to fill the package with the product. Then there is a provision to seal the package and make it ready for transport. Due to this fact, this particular packaging machine is also considered as system packaging.

There are two types of form-fill-seal machines which have got extensive application for the packaging of processed food products.

i) Vertical form-fill-seal machine.
ii) Horizontal form-fill-seal machine.

i) Vertical form-fill-seal machines

This particular machine performs different operations like film formation, back seal production and making top and bottom cross seal simultaneously. The film is fed from a roll and the operations are as follows:

a) Form-fill-tube

Film formation starts at the forming shoulder. In this process, the flat film passes over the shoulder to form a round tube shape with sides overlapping each other. In some cases, machine uses a metal tube to maintain the shape. The back seal could be formed either as LAP, FOLD OVER or FIN to make the basic shape of the pouch or package.

b) Heat seal along back

Once the tubular shape has been formed, the overlapping edges of the flexible packaging materials are sealed. This is normally done with the help of a pair of heated jaws which come together and press the overlap edges of film to make the back or centre seal. In most of the cases, the impulse seal is used for certain film types while other methods such as hot air or high frequency are also used. This machine creates the longitudinal seal that is generally centered on the back of the bag formed at the front of the forming tube.

c) Cross seal formation

Once the tube has been formed with back or centre seal, cross sealing and filling takes place. The bottom of the pouch is then sealed with the help of heating elements in the horizontal jaws and then the seal is cut at the middle and allow to drop the filled package freely. In this case, the horizontal seal where one part act as top seal of the bottom pouch and the other part will be the bottom seal of the subsequent pouch and the operation thus continuous.

Vertical form-fill-seal machines are particularly suited for material that drop freely on its own weight. These are fed by fillers that are normally positioned at the top of the machine. Fillers are (i) gravimetric where a cup is filled, levelled and discharged to the pouch or (ii) auger filler where product volume is measured by the number of revolution of a screw within the tube or (iii) weight fillers based on a scale system where precise quantities by weight are accumulated and released to the bag machine. Edible oil, milk, sugar, cereals, pan masala, spices, tea powder, etc., are packed by this machine.

ii) Horizontal form-fill-seal machine

This type of machine is extensively used for the packaging of processed food products. In this machine, the flexible film is moved horizontally through the machine which form or folds it into a simple 'V' shape. Once 'V' shape is formed, proportional heat control dies make the side seals and the pouches or bags are separated. Horizontal film advancement is intermittent or continuous. This machine has a control device based on electromechanical, electronic or micro processor. Products like chocolates and other confectionery items, sauces, salt, sugar, tomato ketchup, pickles, etc., could be packed by using the machine.

Types of pouches / package formed

By using the form-fill-seal (FFS) machine either vertical or horizontal, the flexible pouches could be made in the form of pillow pouch, 3-side seal pouch or 4 side seal pouch. A single web is used to form pillow pouch or 3 sides seal pouch either by vertical or horizontal FFS machine. In case of pillow pouch, there will be one centre seal at back and two seals, i.e., one at top and the other at bottom. But two numbers of independent web can also be used to make 4 sides seal pouch in this machine. Figure 14.3 illustrates a form-fill-seal machine.

Figure 14.3: A form-fill-seal machine

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you mean by vacuum packaging?

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2. What are the steps followed for gas packaging?

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3. How many types of FFS machines are available in India?

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4. What are the applications of FFS machine for processed food packaging?

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....

5. Fill up the following gaps:

   i) In Vertical FFS machine, the fillers are ____________ , ____________ and ____________.

   ii) In vacuum packaging, the oxygen level is reduced to___________.

   iii) EMA contains ____________ oxygen and ____________ carbon dioxide.

   iv) In active packaging, normally ____________ and ____________ are used to absorb oxygen and ethylene.

   v) In gas flushing technique, inert gas ____________ and ____________ are normally used.

14.9 LET US SUM UP

Food products either in fresh or processed form available in the market are consumed by the human beings. There has been constant growth in production of fresh fruits and vegetables but unfortunately, it is not distributed in proper manner across the country. This is mainly due to improper handling and storage mechanisms and also inadequate packaging. In addition, there could also be other reasons like improper infrastructure facilities and transportation. As the fresh produce is highly perishable in nature and continue to respire there is special requirement of its packaging. Similarly, chilled and frozen foods have different packaging requirements.

Aseptic packaging has got extensive application in the packaging of fruit juices for longer shelf life. The foods which have got high fat content, require modern packaging systems like vacuum and gas packaging to enhance the shelf life of these products in consumer pack. Dehydrated fruits and vegetables have got special requirement of packaging which has also been covered in this unit.

For any packaging system, packaging machinery plays an important role. In fact, good and effective machinery has made possible to pack processed food products without much loss in their quality. Form-fill-seal machine is considered to be one of the important machine for system packaging of variety of food products like powders, granules and pastes.

You have also understood the manufacturing processes for the production of important packaging materials like glass bottles, tin plate containers, plastic films and plastic containers which are normally considered as primary packaging materials. These materials have got wide application in the packaging of processed food products.

In short, you have learnt the important packaging materials, their manufacturing process, packaging systems and machinery in this unit.

14.10 KEY WORDS

Annealing	:	Regulated way of cooling an article to eliminate internal stress and thus breakage.
Throat	:	The channel of the furnace through which the molten glass is passed away.
Parasite	:	The thermoplastic material when extruded in the form of pipe under blow moulding process, is called parasite.
HTST	:	High temperature short time. This is the latest technique of sterilization of food products where the microbes are completely killed within short period of time.
Freeze burn	:	During freezing moisture is lost from the surface of the product, the product tissue becomes dry and tough brownish and a grainy spot occurs on the surface.
Parison	:	A semi finished container or a blank mould made of cast iron, used normally prior to sent the gob into finished mould.
Gob	:	A stream of glass cut off to a predetermined diameter and length of sheats to form a gob.
TBA	:	Tetrabrick aseptic system which was introduced in Indian market by Tetrapak Company in the year of 1970.
TCA	:	Tetra classic aseptic system. This system produces the package of hedronal shape.
EMA	:	Equilibrium modified atmosphere containing 2.5% oxygen and 3.8% carbon dioxide, it can delay the maturation process and the softening of vegetables, microbial spoilage and enzymatic browning.

14.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answers should include the following points:

1.
   - Highly perishable in nature.
   - Changes in colour, texture, odour and flavours.
   - Apearance of micro-organisms like moulds.
   - Damages of delicate tissues due to chilling injury.
   - Loss in moisture causing loss in weight.
2
   - Consumer package:

     Flexible plastic film, plastic punnets, plastic net bag, foam sleeve, plastic crate, shrink wrap, etc.

   - Transport Package:

     - Bamboo basket, wooden box, corrugated fibre board box.
     - Plastic crate, solid fibre board, plastic corrugated box.
     - Jute sacks, plastic woven sacks, multi wall paper sacks.

3. Modified atmosphere packaging where the atmospheric gas mixture is modified inside the package by considering the requirement of fresh fruits and vegetables. The shelf life of fresh fruits and vegetables increases to a great extent in this packaging.

Check Your Progress Exercise 2

Your answers should include the following points:

1.
   - Physical and chemical changes.
   - The effect on tissue of fruits and vegetables.
   - Food spoilage microbiology.

2. i) Physical changes that occur are

   - Freezer burn – a grainy, brownish spot on the surface, tissue becomes dry and tough.
   - Development of off flavour.
   - Changes in texture as the cell wall ruptures due to the formation of ice crystal during freezing.

   ii) Chemical changes that occur are

   - Development of brown colour due to enzymatic browning.
   - Loss of vitamin C.
   - Development of oxidative rancid flavour on the frozen foods.

3.
   - High moisture barrier property
   - Barrier property to avoid oxidative rancidity.

- Light barrier property to control the oxidative rancidity.
- Low temperature resistance.

4. - Dry packs – LDPE, PVDC coated plastic film, Five layered coextruded plastic film (PE/Tie/Nylon/Tie/PE)
   - Tray packs – made of aluminium sheets, plastic corrugated board, 3 ply or 5 ply corrugated fibre board sheet.

Check Your Progress Exercise 3

Your answers should include the following points:

1. - The main constituents are sand, lime stone and soda ash.
   - Other ingredients like arsenic, selenium and cobalt oxides are added to make clear glass.
   - Boron is added to make the glass strong.
   - Carbon and sulphides are added to make amber (brown) coloured glass.

2. - Raw materials are mixed and fed into melting furnace at (1482°C).
   - Melted glass is passed into refining chamber of furnace and then to form a gob.
   - Gob passes through a parison and then to a finished mould at a temperature of 800^0C to form the glass container.
   - Finally, the glass container cools and hardens quickly.

3. - **Decoration Sizing** – Coating/ Lacquering → printing → varnishing.
   - **Assembly Section** – Slitting → Notching → Folding → Soldering/ Cementing.
   - **Press Shop** – Slitting → Component end → Ancillary operation.

4. - Thermoplastic material extruded in the form of pipe is called parasite.
   - Formation of a parison by injection moulding or extrusion process and then stretching the parison.
   - Radial orientation while blowing the parison into mould.
   - Ejection.

Check Your Progress Exercise 4

Your answers should include the following points:

1. Aseptic packaging is a system by which the commercially sterile products are packed in sterilized containers and the filling operations are also held in sterilized environment.

2. - Sterilization of the product before filling.
   - Sterilization of packaging materials or containers before filling operation.
   - Filling of the product into the sterile package by maintaining the aseptic condition.

3. Products are sterilized by means of UHT method where a temperature of –135°C for 3 to 5 seconds are maintained. However, there may be slight variation in temperature and duration depending upon the type of product.

4. • Moist heat at 121–129°C and dry heat at 176–232°C.
   • Hydrogen peroxide at 30 to 50% concentration.
   • Radiation

5. • Carton box
   • Bags and pouches
   • Cups and trays.
   • Bottles and jars.
6. • Fresh milk and flavoured milk
   • Fruit juices
   • Vegetables oil
   • Cream
   • Chocholate milk

Check Your Progress Exercise 5

Your answers should include the following points:

1. Vacuum packaging is a technique by which all the air inside the package is evacuated resulting into collapsing of package around the product so that pressure inside the package is much less than the atmosphere.

2. Replacement of air from inside the package → inert gas or mixture of gases are injected mechanically → package is sealed.

3. • Vertical Form – Fill-Seal machine
   • Horizontal Form – Fill- Seal machine

4. • Vertical FFS Machine.
   • Edible oil, sugar, spices, ghee, pan masala, milk, fruit juices, hydrogenated fat etc.
   • Horizontal FFS Machine.
   • Confectionery, Sauces, Pickles, Tomato ketchup etc.

5. • Gravimetric, augar and weight fillers
   • 1%
   • 2.5% and 3.8%
   • oxygen seavanger and ethylene absorbant
   • Nitrogen and carbondioxide

14.12 SOME USEFUL BOOKS

1. Bikales Norbert M, Moulding of Plastics (1971) WILEY-Interscience, a division of John Wiley & Sons, Inc, New York.

2. Modern Food Packaging (1998) Indian Institute of Packaging, E-2, MIDC Area, Chakala, Andheri (East), Mumbai.

3. Packaging Technology educational volumes, (Set-A) (2001) Indian Institute of Packaging, E-2, MIDC Area, Chakala, Andheri (East), Mumbai.

EXPERIMENT 1 ADEQUACY OF BLANCHING OF FRUITS/ VEGETABLES

Structure

1.1 INTRODUCTION

Inadequate blanching has a negative effect on quality of finished product. As various types of fruits and vegetables differ in size, shape, heat conductivity, and natural levels of their enzymes, blanching treatments have to be established on experimental basis.

The larger the food item, the longer it takes for heat to reach the center. Thus, small fruit or vegetable may be adequately blanched in boiling water in a minute or two; larger ones may require several minutes.

Objectives

After going through this experiment, you should be able to:

- blanch any given fruit or vegetable; and
- determine the blanching time of any given fruit/vegetable.

1.2 EXPERIMENT

1.2.1 Principle

Adequacy of blanching is determined in terms of inactivation of two most important and heat resistant enzymes catalase and peroxidase in vegetables and some fruits. If these are destroyed, then the other significant enzymes would also be inactivated.

1.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/Material)

- Heating vessels (SS Patiala)
- Stainless steel sieve
- Weighing balance
- Measuring cylinders-Plastic
- Heating equipment a) cooking gas cylinder; b) gas burner
- Carrots, Beans, Cabbage, Potatoes
- Potable water
- Labels

- 1% Guaicol in alcohol solution –1 g guaicol is dissolved in about 50 ml of 50% ethyl alcohol and then the volume is made up to 100 ml with the same solvent.
- Peroxide solution 0.3%-5ml perhydrol is brought to 150 ml with distilled water.

1.2.3 Procedure

i) Peel and cut the vegetables into small pieces. Weigh 100g of the prepared vegetable.

ii) Take 400ml water in a beaker and boil. The ratio of water:vegetables is 4:1.

iii) Dip the prepared 100g vegetables in to boiling water and start the timer.

iv) After every 30seconds remove 1g(approx) of vegetables from the beaker and immediately put in cold water.

v) Take this 1g of sample, homogenized in a motar-pestle.

vi) Filter through a muslin cloth and do the tests for the presence of catalase and peroxidase enzyme.

Catalase presence test

Take 1ml of extract and add 1ml of H_2O_2 solution. In the presence of Catalase, a strong oxygen generation (effervescence) is observed for 2-3 minutes.

$$2H_2O_2 \longrightarrow 2\,H_2O + O_2 \uparrow$$

Peroxidase presence test

i) To the same tube to which H_2O_2 is added, add 0.5ml guaicol solution. Keep the tube aside for sometime for colour development.

ii) Appearance of red colour confirms the presence of Peroxidase.

iii) Continue step (4) to (6) till red colour with guaicol ceases to appear.

iv) The time taken from zero minute to the time when red colour is no more observed is called Blanching time for the vegetable under study.

1.2.4 Observation

i) Catalase inactivation time and temperature.

ii) Peroxidase inactivation time and temperature.

Note: For cabbage, Catalase inactivation by blanching is sufficient; blanching further to Peroxidase inactivation would have negative effects on product quality and even complete browning.

For all other vegetables and for potatoes, both tests MUST be negative, for Catalase and for Peroxidase.

Observation Table

Vegetable/Fruit	Time(seconds)	Catalase	Peroxidase

1.2.5 Results

Based on the results of the above exercise, the given vegetable is adequately blanched as no colour development took place.

Absence of colour development indicates adequate blanching.

1.3 PRECAUTIONS

- Select only microbiologically safe vegetables.
- Remove all spoiled, rotten vegetables/fruits.
- Maintain clean, hygienic working atmosphere.

EXPERIMENT 2 CANNING OF FRUITS AND VEGETABLES

Structure

2.1 INTRODUCTION

Canning is a preservation technique used to preserve fruits and vegetables in order to increase their shelf life. It also enables the processor, to store excess amount of fruits and vegetables available in season to be used in off-season.

Objectives

After going through this experiment, you should be able to:

- utilize fruits/vegetables for canning;
- increase the shelf life of the fruit/vegetable; and
- process seasonal fruits/vegetables to be used in off-season.

2.2 EXPERIMENT

2.2.1 Principle

The principle of canning is to sterilize the food inside by a heat process, after sealing the can, to increase its shelf life.

2.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/Material)

- Heating vessels (SS Patiala)
- Stainless steel sieve
- Weighing balance
- Measuring cylinders-Plastic
- Heating equipment a) cooking gas cylinder; b) gas burner
- Double seamers.

2.2.3 Procedure

Testing of cans

The empty cans are tested for leaks with a vacuum or air pressure tester. Can is subjected to the gradual air pressure inside it. It is kept in water and the leakage is determined by bubbling. Thus, the maximum pressure the can is able to withstand is determined.

Specifications for a can is that it should be able to withstand pressure not less than 15 pounds.

Canning of fruits and vegetables

Canning of fruits/vegetables involves the following steps:

A) Preparation of fruit and vegetable for canning

i) Sorting and grading

ii) Washing

iii) Peeling, coring and pitting

The washed fruits and vegetables are prepared for canning by peeling, coring, etc.

a) Peeling

- By hand or with knife
- By machine
- By heat treatment
- By lye solution

b) Cores and pits: In fruits they are removed by hand or by machine. e.g., Pineapple. Coring removes fibres and proteolytic enzymes.

iv) Blanching

B) Filling in the cans

C) Syruping or Brining

D) Liding

E) Exhausting

F) Sealing

Flow Diagram of Canning Operation

Receiving raw material & selection

↓

Weighing

↓

Washing

↓

Cutting into slices

↓

Pitting/Coring

↓

Sorting

↓

Washing

↓

Filling in the pre-sterilized cans

↓

Syruping/Brining

↓

Exhausting

↓

Closing & Sealing

↓

Processing

↓

Cooling

↓

Storage

↓

Marketing

2.2.4 Observations

- Size of the can used
- Amount of fruit or vegetable/Number of cans used
- Time of exhausting
- If there is any leakage
- If there is any swelling of can
- If can remains flat (seems to be normal and properly processed without any defect)
- Tapping sound a) metallic; b) dull.

2.2.5 Results

The given fruit/vegetable is adequately canned. The procedure followed for canning of fruits and vegetables is correct. The can remains flat and without any defect.

2.3 PRECAUTIONS

- The cans used should be checked for corrosion.
- Fruits and vegetables should be absolutely fresh. It should be free from all-unsightly blemishes, insects damage and malformation
- Ripe, firm and evenly matured fruits should be selected. Over ripe fruit is generally infected with microorganisms and would yield a pack of poor quality. Under-ripe fruit will generally shrivel and toughen on canning.
- Worker should wear apron and cover the head with a cap.

EXPERIMENT 3 CUT-OUT ANALYSIS OF CANNED PRODUCT

Structure

3.1 INTRODUCTION

Cut-out analysis refers to the analysis of packed / finished product for various quality parameters. It is done to check the overall acceptability of the canned product.

Objectives

After going through this experiment, you should be able to:

- if the given canned product is as per specifications;
- the adequacy of heat treatment (over-processing or under-processing)
- the condition of the can and the canned product;
- the adequacy of blanching that has been given before processing;
- corrosion of interior of can; and
- other types of microbial spoilage like hard swell or soft swell of can.

3.2 EXPERIMENT

For measuring Salt and acidity you should consult practical of Course-III (BPVI-003) and Course-VII (BPVI-007)

3.2.1 Principle

The testing of overall acceptability of the canned product is done by observing the physical condition of the can and chemical, microbial and organoleptic quality of the products.

3.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/Material)

- Canned products
- Can opener
- Weighing balance
- Refractometer
- Vacuum and pressure gauges
- Seam testing or headspace gauge
- Hot plate
- Burette-50ml capacity

- Pipette-5ml capacity
- Silver nitrate(0.1N)
- Fehling's Solution A and B
- Methylene blue
- Potassium chromate
- Distilled water

3.2.3 Procedure

i) Note the external conditions of can such as body dents or scratches, leakage around seams, condition of ends, etc. In describing the conditions of the can, categorize as per the following:

- Flat cans
- Flipper
- Springer
- Swell

ii) Gross weight: Weigh the can as such and note the gross weight.

iii) Vacuum or Pressure-Use a gauge, which indicates both, vacuum and pressure. Open the can with a good can opener.

iv) Inspection of content: As soon as the can is opened, note the appearance on the surface. Underfilling and overfilling can be seen. Cloudiness in the syrup or brine, or unsatisfactory appearance of the fruit or vegetable must be noted.

v) Gross headspace: This is the distance from the top of the double seam to the surface of the contents of the can. Measure it with a seam-testing gauge or headspace gauge.

vi) Drained weight: Weigh the empty dried sieve. Then, empty the contents of the can in such a manner so as to distribute the product evenly upon a circular sieve which should be so inclined as to facilitate drainage of syrup or brine. Allow the product to drain for 5 minutes.

vii) The drained weight = (weight of the sieve along with the contents- weight of the dry sieve).

viii) Net weight: The net weight is the weight of the contents along with the syrup. Wash the empty can with water and record the empty weight of the can. Subtract the empty weight from gross weight to get the net weight of the contents.

ix) Internal condition of the can: When cans have been emptied and washed, examine the internal surface for evidence of corrosion, blistering or defects in lacquer, pitting, scratching, discolouration, leaks, evidence of scortching along seams, etc. State whether internal surface is lacquered or not.

x) Syrup or brine: Note the colour, clarity and the flavour of syrup or brine. Determine the soluble solids in canned fruits using a refractrometer.

xi) Salt content in brine/total sugars in syrup: For the can containing fruits, determine the total reducing sugars by Lane-Eynon method, whereas for a vegetable, determine the salt content by Mohr's titration.

xii) Inspection of can contents

- *Colour*: It is an essential feature to be considered. Pale or dull appearance makes the product unattractive and unappetizing. Blemished and diseased fruit must be noted very carefully. Discoloration, if any, should be noted.

- *Firmness*: Soft, pulpy or disintegrated fruit pieces must be noted.

- *Flavour:* The flavour is an important factor. Subject the product to a panel of judges and report the flavour in terms of good, acceptable, normal, slight off –flavour or unpalatable.

xiii) Bacteriological examination: The principle of canning is to sterilize the food inside by a heat process after sealing the can. In the canned fruit products, the low pH generally inhibits the growth of bacteria, and only yeasts, moulds and enzymes have to be destroyed. They are comparatively less heat-resistant and are killed by heating for a short period in boiling water. Vegetables of a pH higher than 4.5 are capable of supporting the growth of heat resistant spore forming organisms and hence their processing is based on destruction of spores of toxin producing *Clostridium botulinum.* Sometimes leaker spoilage may occur, which is a post-processing spoilage caused by the percolation of the cooling water through the unsettled seam immediately after processing.

To detect the presence of living bacteria in the canned product, incubate the cans at 37°C and 55°C for 7 days. The organisms growing at 37°C usually cause spoilage accompanied by the production of gas (CO_2) which causes the cans to become springers and then a hard swell. If left too long in the incubator, the cans may blow up. A can, which swells at 37°C indicates the presence of living mesophilic organism, usually caused by leakage.

Subject the swollen cans for bacteriological examinations-TPC, yeast and moulds etc.

3.2.4 Observations

Record the observations in a cut out proforma as mentioned below:

Cut-out Performa

A) Product Details

i) Name of the product
ii) Date of manufacture
iii) Date of inspection
iv) Description of the product

B) Inspection of the can conditions

i) Size of the can
ii) External appearance
iii) Condition of ends of can
iv) Vacuum
v) Gross weight
vi) Headspace
vii) Drain weight
viii) Weight of empty can

ix) Net weight
x) Weight of syrup
xi) No. of pieces
xii) Internal can corrosion

C) Inspection of cans content-organoleptic evaluation

i) Slices Appearance
Colour
Texture
Taste
Foreign matter

ii) Syrup Appearance
Color
°Brix

D) Microbiological examination

3.2.5 Results

FPO specifies standards for canned products. Compare the results obtained with the following FPO standards for canned products, tabulate as per the table given below and conclude whether the given canned product complies the FPO standards.

S. No.	Parameter	FPO standard	Results for given canned product	Comments
	CANNED FRUITS			
1.	**Drained weight**	Not less than 50%, Exception Berry fruits-40%		
2.	**Drained solids**			
2a)	Appearance	Free from blemished,stalks,leaves etc		
2b)	Texture	Free from disintegration, damage from bruises and uniformly prepared		
2c)	Organoleptic quality	Characteristic taste		
3.	**On whole product**			
3a)	Preservatives	Not permitted		
3b)	Added colour	Permitted only in cherry & strawberry		
	CANNED VEGETABLES			
1.	**Drained weight**	Not less than 55%, Exception canned tomatoes-50%		

2.	**On Solids**			
2a)	Appearance	Free from pods, stalks, detached skins, woody fibres, roots and blemishes.		
2b)	Texture	Free from disintegration, damage from bruises		
3.	**On Brine**			
3a)	Added colour	Not permitted except for processed peas		
3b)	Preservatives	Not permitted		

3.3 PRECAUTIONS

- Maintain clean and hygienic working atmosphere.
- Titration should be done as rapidly as possible.
- Normality of silver nitrate should be checked.

EXPERIMENT 4 TESTING OF FLEXIBLE PACKAGING MATERIAL

Structure

4.1 INTRODUCTION

All foods undergo varying degrees of physical, chemical and biological deterioration during storage. This may lead to losses in organoleptic quality, nutritional value, safety and aesthetic appeal of the food product.

The highly sensitive organic and inorganic compounds which make up food that contribute to texture and consistency of unprocessed and manufactured products are affected by nearly every variable in the environment. Heat, cold, light and other radiation, oxygen, moisture, dryness, natural food enzymes, microorganisms, industrial contaminants, time, etc., can adversely affect foods.

Therefore, packaging food in suitable materials is of paramount importance in increasing the shelf life of the products. Packaging is the physical entity that functions as the wall between the contents and the exterior.

Seal strength/Tensile strength is a fundamental property indicative of the serviceability of the packaging material. In the packaging of food products, tensile strength of a flexible packaging **material determines the resistance to rupture when subjected to a pulling force**. Packaging materials of high tensile strength are required when packages are made in semi-automatic pouch forming and filling machines, and to hold heavy packaged items. It is measured using a Instron tensile strength measuring machine

Another property, Elongation at break is also an important parameter of a flexible packaging material, especially for food products which are likely to experience drops during distribution. Such materials need to have a higher elongation property. It is measured on the same machine as that of tensile strength, and **is a measure of the extent to which materials will stretch before breaking.**

Objectives

After going through this experiment, you should be able to:

- test the quality standard of packaging materials;
- predict the quality and shelf-life of the processed product;
- determine the tensile strength/seal strength of the pack; and
- elongation at break.

4.2 EXPERIMENT

Testing methods can be divided into:

i) Chemical parameters: Identification of the plastics, resistance to grease, etc.

ii) Mechanical parameters: Barrier properties, strength, heat-seal ability and clarity

In our practical course, we would be doing the following three main tests

i) Water Vapour Transmission rate (WVTR)
ii) Leak test
iii) Seal strength

The procedure and details for each of the above mentioned methods are described below in Experiment Nos. 4a, 4b and 4c, respectively.

EXPERIMENT 4A TO DETERMINE THE WATER VAPOUR TRANSMISSION RATE (WVTR) FOR THE GIVEN PACKAGING MATERIAL/ PRODUCT PACK

Structure

4A.2 EXPERIMENT

4A.2.1 Principle

The water vapour permeability of the package is defined as the rate at which water is transmitted into the package from the test atmosphere (Normally 90± 2% RH at 37.8° C ± 1°C) surrounding it while a desiccant is sealed within.

4A.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/ Material)

- Anhydrous calcium chloride
- Humidity Cabinet – It should have a provision for circulation of air
- Analytical balance-Readability of 0.0001g
- Oven

4A.2.3 Procedure

i) Dry anhydrous calcium chloride in an oven at 200°C for 1 hour.

ii) Place known weight of the desiccant within the pack to be tested. The weight should be more than the half capacity of the pack. Prepare three such experimental samples.

iii) Label each pack as 1, 2, and 3. Seal the packs and record the weight for each pack.

iv) Pre-warm the sealed packets at 37.8°C. Place the warm samples in the test chamber/humidity cabinet maintained at 90±2% R H and 37.8±1°C.

v) Remove one pack from the chamber after 24 hours, weigh and immediately place it back. Repeat the same for all packs.

vi) Repeat the above, till no change in the weight gain is observed.

4A.2.4 Observations

i) Plot the weight gained against time.

ii) The end point is indicated by at least three successive points on a straight line.

iii) The slope of this portion of the curve is measure water vapour permeability.

4A.2.5 Results

- Calculate the average Water Vapour Transmission Rate for the sample by taking the average of the slopes obtained for the three packs.

- Report the water vapour permeability as grams of water per 15 days (till whatever time the weight gain becomes constant) for the package as a unit.

4A.3 PRECAUTIONS

- For accurate weighing, check the bubble of the analytical balance and adjust it to the centre.

- While weighing the packs, care must be taken to take out only one pack at a time and immediately place it back after recording the weight.

- Carry out the experiment in triplicates in order to get most representative results.

EXPERIMENT 4B TO PERFORM THE LEAK TEST ON THE GIVEN FOOD PRODUCT PACK

Structure

4B.2 EXPERIMENT

4B.2.1 Principle

Leak test is done to check: 1) if the seal integrity of the pouch/pack is proper or not 2) if the seal integrity is good enough to undergo handling during transportation.

It is usually used as an online check to see if all the settings of temperature and pressure of the sealing machine are correct.

4B.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/ Material)

- Water bath.

4B.2.3 Procedure

i) Fill the water bath with water up to the indicated level.

ii) Hold the pack to be tested from the upper most corners and immerse the same in water while holding it tightly with both the hands.

iii) Observe for the bubbles rising from the seal areas of the pack.

4B.2.4 Observations

- Report if there is any air bubble.

4B.2.5 Results

Air bubbles rising in the water bath indicate a leak in the pack. Hence, the product will not be stable till the indicated period as mentioned on the pack.

If no bubbles are observed, it may be concluded that the product seal is intact and pack is free from any leak.

EXPERIMENT 4C TO DETERMINE THE SEAL STRENGTH OF THE GIVEN PACK

Structure

4C.2 EXPERIMENT

4C.2.1 Principle

The strength of the seal in a flexible packaging is determined by the temperature, pressure and time of sealing. The tensile strength and elongation of the flexible material are important parameter to check the seal strength.

4C.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/ Material)

- Instron Tensile Strength Testing Machine

4C.2.3 Procedure

i) Select the packs to be tested for the seal strength.

ii) Cut the back seal of the pack (or top seal/bottom seal whichever is to be tested) yielding a strip about 15mm wide and maximum 50mm in length. Care should be taken not to cut off any of the back heat seal region (or top seal/bottom seal whichever is to be tested).

iii) Place the seal specimen in the Intron tensile test clamps.

iv) Set the machine at a pull rate of 15mm/min using a 5 Kg load cell is used.

v) Begin the test pull. Record the peak value (g/15mm) obtained.

4C.2.4 Observations

i) Calculate the maximum force(peak value) from the chart recorder and record as g/inch.

ii) Following parameters may also be calculated or noted directly from the machine:

   a) Breaking Factor, Kg/cm=Maximum Load/original thickness of specimen.

   b) Tensile strength at break, Kg/cm2= Maximum load at break/Original minimum cross-sectional area of specimen.

   c) Elongation at break %= Elongation at the moment of rupture of specimen/Initial length of specimen*100.

4C.2.5 Results

- The results are expressed as maximum force required in grams/inch.

  A larger value for elongation is an index of toughness, since it indicates that the material will absorb large amounts of energy before breaking.

4C.3 PRECAUTIONS

- Care should be taken while cutting the test specimen. A precision cutter with sharp edges should be used so that there is no damage to the seal area to be tested.
- The material placed between the jaws should not be touched while the test is running.
- Calibrate the equipment, as mentioned in the manual provided along with the instrument, before conducting the test.

EXPERIMENT 5 PREPARATION OF FRUIT-BASED CARBONATED DRINKS

Structure

5.1 INTRODUCTION

People of all age groups consume beverages to quench their thirst. These beverages are non-alcoholic and include fruit based drinks, synthetic drinks, sweetened aerated water or carbonated drinks. The cold drinks are in demand for greater part of the year in the country. India produces more than four thousand million bottles of aerated water annually. This aerated water contains synthetic colouring and flavouring additives, which may potentially be allergenic. It is a huge business in comparison to fruit juices and beverages. These aerated waters if fortified / substituted with fruit juices will provide more nutrition than aerated water and would prove a boon to the consumer as well as grower.

Thus, the fruit based carbonated beverages can provide a new product having natural colour and flavour along with nutrition.

Objectives

After going through this experiment, you should be able to:

- utilize fruit juices for new type of beverages;
- produce fruit based carbonated drinks;
- avoid use of synthetic colouring and flavouring agents; and
- utilize indigenous fruits.

5.2 EXPERIMENT

5.2.1 Principle

The fruit based carbonated drinks can be produced and preserved by hurdle technology, i.e., chemical preservative, carbon dioxide and heat treatment without addition of synthetic colouring and flavouring additives.

5.2.2 Requirements (Equipment/Machinery/ Instrument and Chemicals/ Material)

a) Preparation and preservation of fruit juice

- Fruit mill
- Hydraulic press
- Stainless steel (S.S.) Tanks
- Heating vessels (S.S. Patiala)
- Stainless steel sieve
- Glass bottles
- Crown corking machine
- Crown corks
- Heating equipment a) Cooking gas cylinder; b) Gas burner
- Thermometer
- Weighing balance

b) Preparation of carbonated fruit drinks

- Carbonating machine including CO_2 gas cylinder
- Water chiller
- Water filtering unit

c) Chemicals / materials

- Fruit juice, (Fruits-Jamun, Amla, Lime and coloured grapes)
- Sugar
- Citric acid
- Sodium benzoate
- Labels
- Carbon dioxide gas
- Potable water
- Filtration cloth

5.2.3 Procedure

a) Preparation and preservation of fruit juices

Fully ripe fruits are selected; injured and spoiled fruits are sorted out. Cull fruits can also be used. Fruits are cleaned and washed thoroughly with clean water. Fruits are crushed in a fruit mill and the crushed mass is pressed into a hydraulic press to get juice. The juice is filtered and preserved either by chemical preservative or by heat application (i.e., pasteurization or sterilization). The processed fruit juice could be stored at refrigerated temperature for better quality during storage.

b) Preparation of carbonated fruit drinks

Preparation of fruit syrup: Carbonated drinks are made by post-mixed method. Fresh or preserved fruit juice is used to prepare syrup base. Syrup base is prepared by mixing fruit juice, sugar, citric acid and water and preserved by sodium benzoate. These ingredients are mixed in such a way so that the syrup base has 50% (or °Brix) total soluble solids and 1.0% acidity.

The general formulations based upon our past experience of commercial productions are given in the box below:

Recipes	Aonla	Grape	Jamun	Lime
Juice (kg)	1.0	1.0	1.0	1.0
Sugar (kg)	1.17	1.066	1.16	3.254
Citric acid (g)	11.43	12.00	11.11	-
Water (kg)	0.322	0.443	0.341	2.254
Sodium benzoate (g)	1.25	1.25	1.25	3.25
Total (Kg)	2.50	2.50	2.50	6.50

The amount of above ingredients may be altered as per requirement.

The sugar and citric acid are dissolved in water by heating to a boil, filter through a four-fold muslin cloth and then cooled. After cooling it is mixed with the juice thoroughly. The sodium benzoate is mixed with a small quantity of clean water and then mixed thoroughly with the syrup base and filled into the clean and presterilized glass bottles leaving a head space of 4 cm and sealed by crown corking, labelled and stored at low temperature (5-6°C).

Carbonation: The properly filtered clean water is chilled to a temperature of 4°C. The chilled water is taken into the carbonator and the desired pressure of carbon dioxide gas is maintained, so desired gas volume is achieved in the finished drink when measured.

The desired amount (50g) of a fruit juice syrup is dosed into the previously sterilized and clean glass bottles (200 ml capacity) and then filled with the carbonated chilled water and sealed by crown corking.

The fruit based carbonated drinks can be stored for a week if prepared without preservative. But if preserved with sodium benzoate and heat processing then it can be stored for a period of 3 months at ambient temperature (30°C) under dark conditions and 6 months if stored at low temperature (6-7°C).

Heat processing: Bottles are placed in the water heated to a temperature of 70°C in a stainless steel or aluminium vessel so as to maintain a temperature of 66°C for 30 minutes in the contents of the bottle. After heat processing, the bottles are removed and cooled under fan. After cooling, bottles are washed, shaken a little bit and stored, labelled and marketed as and when required.

5.2.4 Observations

In fruit juice and syrup base

i) Total soluble solids (TSS)
ii) Acidity
iii) pH

In final carbonated fruit drinks

i) TSS
ii) Acidity

iii) PH
iv) CO_2 gas volume
v) Sensory quality on the basis of colour, flavour and taste (0-9 score of Hedonic scale)

For measuring TSS, acidity and pH you should consult the practical manual III Food Chemistry and Physiology and VII Food quality Testing and Evaluation.

Calculations

CO_2 gas volume: For measuring gas volume in a carbonated beverage, a gas volume tester is required. It is screwed on the top of the neck of the bottle. By pressing the handle crown cork is punctured and gas pressure is observed in the pressure gauge which is released by unscrewing the side valve until the first bubble rise in the liquid. Then shut the valve and shake the bottle until gauge reaches maximum pressure. Note the pressure on the gauge. Remove the crown cork and note the temperature of the drink. With these values, gas volume is seen through a Table 5.1. Gas volume denotes how many gas volumes are dissolved in one volume of liquid.

5.2.5 Results

Analysis of finished beverage

- Gas volume (gas volume about 2.5 to 3.5 are acceptable for fruit based drinks)
- TSS
- pH
- Acidity
- Sensory quality

The product which has received a score of 5.5 and above is acceptable.

Any abnormal change in TSS, acidity or pH will indicate that the product is not fit for consumption.

5.3 PRECAUTIONS

- Select only microbiologically safe fruits.
- Remove all spoiled, rotten fruits.
- Thick glass bottles should be used, which can sustain CO_2 gas pressure.
- Maintain clean, hygienic working atmosphere.
- Workers should wear apron and head gear.
- Proper CO_2 gas pressure should be maintained in the cylinder containing chilled water.

Table 5.1: Gas volume test chart (Volumes of carbon dioxide dissolved by 1 volume of water)

Temp., (°F) in bottle — **Gauge pressure of bottle (lbs. per sq. in)**

	16[a]	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64
	2.7	2.9	3.1	3.3	3.4	3.6	3.8	4.0	4.1	4.3	4.5	4.7	4.8	5.0	5.2	5.4	5.6	5.7	5.9	6.1	6.2	6.4	6.6	6.8	6.9
46	2.7	2.8	3.1	3.2	3.4	3.5	3.7	3.9	4.0	4.2	4.4	4.6	4.7	4.9	5.1	5.3	5.4	5.6	5.8	6.0	6.1	6.3	6.4	6.6	6.8
47	2.6	2.8	3.0	3.1	3.3	3.5	3.6	3.8	4.0	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.3	5.5	5.7	5.9	6.0	6.2	6.3	6.5	6.7
48	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.7	3.9	4.1	4.2	4.4	4.6	4.7	4.9	5.1	5.2	5.4	5.6	5.7	5.9	6.1	6.2	6.4	6.6
49	2.5	2.7	2.9	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.1	4.3	4.5	4.6	4.8	5.0	5.1	5.3	5.5	5.6	5.8	6.0	6.1	6.3	6.4
50	2.5	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.4	4.5	4.7	4.9	5.0	5.2	5.4	5.5	5.7	5.9	6.0	6.2	6.3
51	2.4	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.6	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	6.1	6.2
52	2.4	2.5	2.7	2.8	3.0	3.2	3.3	3.5	3.6	3.8	3.9	4.0	4.2	4.4	4.5	4.7	4.9	5.0	5.2	5.3	5.5	5.6	5.8	5.9	6.1
53	2.3	2.5	2.7	2.8	2.9	3.1	3.3	3.4	3.6	3.7	3.8	4.0	4.2	4.3	4.4	4.6	4.8	4.9	5.1	5.2	5.4	5.5	5.7	5.9	6.0
54	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.8	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.2	5.3	5.4	5.6	5.7	5.9
55	2.3	2.4	2.6	2.7	2.8	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.6	4.7	4.9	5.1	5.2	5.3	5.5	5.6	5.8
56	2.2	2.4	2.6	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.1	5.2	5.4	5.5	5.7
57	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.4	5.6
58	2.1	2.3	2.5	2.6	2.7	2.8	3.0	3.1	3.3	3.4	3.5	3.7	3.8	3.9	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5.1	5.2	5.3	5.5
59	2.1	2.2	2.4	2.5	2.7	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.7	3.9	4.0	4.2	4.3	4.4	4.6	4.7	4.8	5.0	5.1	5.3	5.4
60	2.1	2.2	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.3	3.4	3.5	3.7	3.8	3.9	4.1	4.2	4.3	4.5	4.6	4.7	4.9	5.0	5.2	5.3
61	2.0	2.2	2.3	2.4	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.5	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2
62	2.0	2.1	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.6	4.7	4.8	5.0	5.1
63	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0
64	1.9	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.1	4.2	4.3	4.4	4.6	4.7	4.8	4.9
65	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.8
66	1.9	2.0	2.2	2.2	2.4	2.5	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.1	4.2	4.3	4.4	4.5	4.7	4.8
67	1.8	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.7	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.6	4.7
68	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6
69	1.8	1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5
70	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.5
71	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.6	3.7	3.9	4.0	4.1	4.2	4.3	4.4
72	1.7	1.8	1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3
73	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
74	1.6	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
75	1.6	1.7	1.8	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1
76	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.4	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1
77	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0
78	1.5	1.6	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.9	3.1	3.1	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0
79	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9

A figure in this column represent the volume of carbon dioxide gas (reduced to 0º and 760 mm.) dissolved by I volume of water at the temperatures indicated, if the partial pressure of the carbon dioxide gas is 760 mm. Hg, solubility data correspond to Bohr and Bock published in Landolt-Bornstein, Physikalische-Chemische Tabellen. Figures in body of the table were calculated for various temperatures and pressures based on the Boyle-Mariotte law for isothermal compression.

Source: The Chemistry and Technology of Food and Food Product, by M.B. Jacobs, 1951, 2nd Edn., Vol. III, p. 2374.

UNIT 1 DEFINITION AND IMPORTANCE OF QUALITY

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- define food quality;
- state the quality specifications for consumers;
- classify and explain food quality attributes; and
- explain food borne hazards and infections.

1.1 INTRODUCTION

Food quality and safety are the two of the most important aspects of food processing. Therefore an understanding of what constitute food quality is very essential. Equal or more important is ensuring food safety. Food poisoning through microbial and viral means is a major concern.

An efficient quality control department in a food processing unit plays vital role in ensuring both quality and safety. These aspects are dealt with in this unit.

1.2 DEFINITION OF FOOD QUALITY

Quality of foods may be defined as the composite of those characteristics that differentiate individual units of product; these characteristics should have significance in determining the degree of acceptability of that unit by the buyer.

Some important characteristics of the food / food products are:

- Colour and gloss, viscosity and consistency, size and shape, texture and flavour.
- Nutritive values (vitamins, minerals) – hidden attributes.

Quality is commonly thought of as degree of excellence. It may be considered as a set of specifications, which are to be met within given tolerances or limits. Quality Control may be defined as the maintenance of quality at levels and tolerances acceptable to the buyer while minimizing cost for the vendor.

1.3 FOOD QUALITY ATTRIBUTES

The quality attributes referred to as sensory may readily be classified in accordance with the human senses by which they are perceived. The sensory attributes namely, the senses of sight, touch, taste and smell are given in Table 1.1.

Table 1.1: Classification of quality attributes

Sight	—	• Appearance • Colour • Gloss • Viscosity • Size and shape • Defects
Touch	—	• Kinesthetic (texture) • Hand or finger feel • Mouth feel
Smell and taste	—	• Flavour • Odour • Taste
Hidden	—	• Nutritive value • Adulterants • Toxicity

Some of the important sensory quality attributes are described below:

Colour and gloss

Colour is an appearance property due to spectral distribution of light. Glossiness, transparency, haziness, and turbidity are properties of materials due to the differences in reflectance and transmittance of light.

Physically, colour is a characteristic of light, measurable in terms of intensity and wavelength. It arises from the presence of light in greater intensities at some wavelengths than of others.

Light may be reflected, transmitted, absorbed, or refracted by the object being illuminated. Spectrophotometers are used to measure colour of the products.

Viscosity

Viscosity or consistency is an appearance property of great importance to food products such as ketchup, creams, juices, pulp, jams, jellies, syrups, etc. The measurement may be used to indicate the consistency of the products. It may also be used as an index to the amount of ingredient in the product.

Liquids flow as if they were composed of individual layers. The friction resulting from the resistance to flow between the liquid layers is called apparent viscosity. Brooke field or Ostwald viscometer is used to determine the viscosity of the product.

Size and shape

Grading into various size and shape categories is usually one of the first steps in food processing operations. This may be accomplished by hand or by means of mechanical sorters, using screens, reels, slots, etc. Grading helps in maintaining uniformity.

- *Defects*

  Defects have been defined as "imperfections, due to the absence of something necessary for perfection, or the presence of something that distracts from perfection".

  In grading foods for defects, tolerances may be established in terms of maximum numbers of defective units allowable.

  Defects may be classified into:

  1. Genetic – physiological,
  2. Entomological,
  3. Pathological,
  4. Mechanical, and
  5. Extraneous or foreign matter.

Kinesthetics of texture

Kinesthetic characteristics deal with the sense of feel. They can be classified as follows:

Finger feel:

- Firmness as encountered by the customer selecting a firm apple, measured physically by compression.
- Softness or yield quality as in selecting a peach, or plum measured physically by compression.
- Juiciness as in immature sweet corns where the thumbnail is used to test the ease and amount of juice squeezed out of a kernel.

Mouth feel:

- Chewiness, as sensed by the resistance of the product to compression and shearing action of the teeth.
- Fibrousness as sensed by the presence of an inedible residue remaining in the mouth after mastication, as well as resistance to cutting forces of the teeth.
- Grittiness, as sensed by the presence of small grit particles, such as sand, or stone cells.
- Mealiness, as sensed by the coating of starch or other material with adhesive properties, over mouth tissues.

- Stickiness, as sensed by the mouth while chewing foods with adhesive properties.
- Oiliness, as sensed in the mouth, caused by oily or soapy products.

The characteristics may be determined by tenderometers, texture meters, puncture meters, succulo meters, fibro meters and pressure testers.

Flavour

Flavour includes taste and odour/ aroma. Taste is a four-dimensional phenomenon, consisting of sweet, sour, salt and bitter. Sweetness can be measured by use of refractometers, sourness by pH meters, and saltiness by flame photometer or by argentometric titration. Bitterness is not estimated but compared to that of quinine sulfate. Odour/ aroma is determined by gas chromatography.

Hidden characteristics

The hidden characteristics of quality are those, which the consumer cannot evaluate with his senses, and yet are of real importance to his health and economic welfare. Nutritive value is one of the hidden characteristics, which is now considered by the consumer as an important attribute. Adulterants and toxins are the other hidden characteristics. Toxins can be microbial toxins, pesticide residues or heavy metals.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define food quality.

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2. Explain the important quality characteristics of food.

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3. What constitute the hidden characteristics of food?

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1.4 QUALITY SPECIFICATIONS FOR THE CONSUMER

The Quality Control System – should be properly geared to meet the consumer's specifications, the quality control cycle usually begins and ends with the customer's specifications.

1st Step : Determine what are the customer's specifications for the product.

2nd Step : Set up procedures to measure these specifications, objectives; scientific methods should be used as far as possible.

3rd Step : Workout the sampling schedule and set up control points in the plant.

4th Step : Final inspection of the finished product.

1.5 FOOD BORNE HAZARDS / FOOD POISONING

In recent years, a number of bacteria, viruses and parasites have emerged as food-borne pathogens resulting in numerous food-borne disease outbreaks. Genetic changes in microorganisms resulting in increased virulence, changes in social attitudes and eating habits, changes in food production and distribution systems and demographic shifts are some of the factors responsible for this.

1.5.1 Microbial Infections

Bacillus cereus

Bacillus cereus is a Gram-positive, motile, spore -forming, facultative anaerobic rod. It is ubiquitous in nature, commonly found in soil (especially rice, paddy, soil) and vegetation. It has been isolated from many foods, including cereal and cereal derivatives, spices, milk and dairy products, vanilla sauce, recipe dishes, chicken soup, mashed potatoes, vegetables, rice dishes and dried foods.

Bacillus cereus can cause two distinctive forms of food poisoning caused by enterotoxins. Emetic food poisoning is caused by the ingestion of emetic toxin that has been pre-formed in food. It causes general malaise, nausea and vomiting and occasionally diarrhoea. This type of food poisoning has been linked with starchy foods such as cooked rice, pasta and noodles. Diarrhoeal food poisoning is caused from the formation and release of enterotoxin in the small intestine. However, the enterotoxin can also be pre-formed in food.

Clostridium botulinum

Clostridium botulinum is a Gram- positive rod. It is a spore-former and an obligate anaerobe. It is ubiquitous, so is widely distributed in soil and marine sediments throughout the world. It is also found in the intestinal tract of animals, including fish.

Non-proteolytic strains of Clostridium botulinum are psychrotrophic. It is because of their non-proteolytic characteristics, that their growth in foods cannot be detected by off-odours and off-flavours. The risk of toxin production prior to the food becoming unacceptable to the consumer is considerably higher than in those foods contaminated with proteolytic strains. In the spore form, it is resistant to heat treatments such as pasteurization. A heat process called a "Botulinum Cook" at high temperatures is commonly recommended for low acid canned products.

Clostridium botulinum produces preformed toxins. The toxin itself can be destroyed by heat treatment (80°C or above) for only a few seconds. Botulism is extremely serious and unless recognized and treated promptly, carries a high risk of mortality. It is the most severe form of food poisoning.

Most of the outbreaks of botulism have been associated with products of fish or marine animals, meat and fruit and vegetables - including mushrooms. Insufficiently heated, canned and bottled foods are at high risk as these provide the anaerobic environment required by the organism to grow. Other inadequately processed products such as farm-cured pork products or those produced where process control is insufficient e.g. traditional fermented products have also been implicated in outbreaks.

Salmonella

Salmonella is a Gram-negative motile rod. It is non-spore forming and facultatively anaerobic in nature. Pasteurization and equivalent heat treatments will generally destroy the organism.

The main source of *Salmonella* for man is food from infected food animals. These animals become infected via the environment, contaminated feed or water, or from other infected animals, birds or rodents. Therefore, meat, poultry, raw milk and eggs should be considered as potentially contaminated with *Salmonella.*

Types of foods involved in food borne salmonellosis have been wide -ranging, but involve mainly poultry and meat products, egg and egg products, cereal and grain products, desiccated coconut, chocolate and dairy products.

The clinical disease of *Salmonella* infection is gastroenteritis. It is one of the main causes of food borne illness the world over. Although death from salmonellosis is rare, it can occur in "at risk" groups, e.g. infants, the elderly and the immuno -compromised (such as hospital patients).

Listeria monocytogenes

Listeria monocytogenes is a Gram -positive, non-sporing rod. It is aerobic and facultatively anaerobic in nature. *Listeria monocytogenes* is psychrotrophic in nature Of all the non-sporing, vegetative food pathogens, Listeria is the most heat resistant. It is, however, generally agreed that milk pasteurization will destroy normal levels of *L. monocytogenes* in milk.

Listeria is ubiquitous in the environment and so can be transferred to foods from a wide variety of sources. Infection from Listeria can also originate from direct or indirect contact with animals (sheep and cows can both excrete *L. monocytogenes* in faeces and sometimes in milk).

Listeriosis is a comparatively rare disease; however, because of the potential severity of the disease, measures for its control in foods are very important. It is generally agreed that the majority of cases of listeriosis are food borne and may be preventable. Symptoms are typically meningitis or septicaemia and in pregnant women it can cause a flu-like illness, which can result in miscarriage, stillbirth or birth of a severely ill infant.

Staphylococcus aureus

Staphylococcus aureus is a Gram-positive coccus. It is a non-motile, non-sporing, facultative anaerobe. Staphylococcus aureus can grow within the temperature range 7°C – 48°C, with an optimum of 35°C – 37°C.

Although *Staphylococcus aureus* is a ubiquitous organism, the largest reservoir of enterotoxin producing staphylococci is man. Therefore, the presence of *staphylococci* in cooked or processed foods can serve to indicate poor hygiene amongst food handlers. Animals may also act as a source of *Staphylococcus aureus*. Typically raw milk and raw meat (particularly pork) may be contaminated with the organism. Some strains of *Staphylococcus aureus* are capable of producing heat-stable toxins (enterotoxins) in food. It is the toxin that causes the typical symptoms associated with *Staphylococcus aureus* food poisoning. Typical symptoms are nausea and vomiting with occasional abdominal cramping and diarrhoea. Foods involved in *Staphylococcus aureus* food poisoning are typically those that have been handled and then temperature abused prior to consumption. Foods implicated in Staphylococcus aureus food poisoning have been cooked meats (notably salted meat such as ham), poultry products, custard or cream -filled pastries, egg foods, cheese, prawns and salads containing potato.

Shigella spp

The genus Shigella consists of four species: *S. dysenteriae* (subgroup A), *S. flexneri* (subgroup B), *S. boydii* (subgroup C), and *S. sonnei* (subgroup D). -sporulating, non -motile rods in the family *Enterobacteriaceae.*

Shigellosis, although commonly regarded as waterborne, is also a food borne disease restricted primarily to higher primates, including humans. Food handlers with poor personal hygiene usually spread it among humans. Foods most often incriminated in the transmission have been potato salad, shellfish, raw vegetables, and Mexican dishes.

Vibrio cholerae

The genus *Vibrio* includes Gram-negative, oxidase-positive (except two species), rod- or curved rod-shaped facultative anaerobes. Many *Vibrio* spp. are pathogenic to humans and have been implicated in food borne disease. Pathogenic *V. cholerae* produces a heat-sensitive enterotoxin that causes the characteristic cholera symptoms, including "rice water stool."

1.5.2 Water and Food Associated Viruses

Several viruses like *Hepatitis* A, *Norwalk* and *Norwalk* like viruses; *Poliovirus* and *Echovirus* may cause food borne disease. Some of the other viruses that have also been associated with food are: *Astrovirus, Calcivius, Enteric Adenovirus, Parvovirus* and *Rotavirus*. These enteric viruses replicate in the intestine of infected individuals and are transmitted by faecal-oral route. The most common types of food-borne viral diseases are *Hepatitis A* (infectious hepatitis) and acute viral gastroenteritis.

The *Hepatitis* A virus (HAV) is one of more than 70 members of enterovirus group of *Picronaviridae* family. Food borne viral gastroenteritis is usually a mild disease with various degrees of nausea, diarrhoea, malaise, abdominal pain, muscle pain, anorexia, headache, and low-grade fever. Illness develops 20 to 50 hours after the consumption of contaminated food and lasts for 1 to 8 days.

Ice, water, ice cream, milk, pastries, salads, sandwiches, shellfish, and other foods consumed raw or subjected to additional handling after cooking are major food vehicles for virus transmission.

1.5.3 Preventive Measures

Prevention and control of food borne disease depends on careful food production, handling of raw products and preparation of finished products. Hazards can be introduced at any point from field to table. The 20th century witnessed revolution in food sanitation and hygiene including refrigeration, chlorination of drinking water, pasteurization of milk, potassium permanganate washing of root vegetables like carrots, lettuce etc. which was a consequence of applied technologies.

Chlorination of drinking water sources for food animals, sanitary slaughter and processing of meat, poultry and seafood, irradiation and other microbial reduction measures for raw agricultural commodities are significant as approaches for food safety. Hazard Analysis Critical Control Point (HACCP) process occurs when monitoring and control technologies are systematically applied to food production to prevent food borne illnesses.

Food cooks are the last but one point of critical control before meal is consumed, the last being those responsible for meal service on the table or in the dishes. Therefore, interventions to promote safe food practices are needed.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give three examples of microorganisms causing food poisoning and indicate the probable causes for the infections.

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2. Briefly discuss water and food borne viral infections.

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3. Suggest a few measures to prevent food poisoning.

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1.6 FUNCTIONS OF QUALITY CONTROL

A well functioning quality control organization will contribute to the reduction of rejects, maintenance of uniform quality, increased customer satisfaction and employee morale.

Some of the specific responsibilities of Quality Control Department are listed below:

- Inspection of supplies and materials.
- Scheduling of operations.
- Measurement of production efficiency.
- Inspection of the finished products.
- Shipping and storage controls.
- Preparation of specifications and procedures.
- Sanitation inspections.
- Conformance to food regulations.
- Waste disposal control.

The quality control department to be effective should have good liaison with the other departments like Sales and Purchase, Production, Research and

Development etc. and also should have complete support from the management.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Indicate five functions of a quality control department.

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1.7 LET US SUM UP

Quality is the composite of those characteristics of which determine the degree of its acceptability by the consumer. The characteristics of food include measurable characteristics like colour and appearance, texture, flavour and also hidden characteristics like nutritive value, presence or absence of adulterants or toxicants.

There is a number of food borne infections. A large number of microorganisms are implicated in food poisoning. Besides, some water borne viruses are also of great concern.

An efficient quality control system in a food processing unit has a major role to play in maintaining consistent quality of finished products and ensure food safety.

1.8 KEY WORDS

Food quality : The composite of those characteristics of food determining the degree of acceptability by the consumer.

Colour : Colour is an appearance property due to spectral distribution of light.

Viscosity : The resistance to flow of a liquid is termed viscosity.

Kinesthetic of texture : Texture perception by feel.

Flavour : Combined sensory perceptions of taste and aroma.

Hidden characteristics	:	Nutrients content and presence or absence of adulterants and toxicants.
Botulism	:	Food poisoning caused by *Clostridium botulinum*.

1.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following:
   - Characteristics differentiating individual units.
   - Degree of acceptability
2. Your answer should include the following:
   - Colour, texture, appearance.
   - Nutrients, toxicants
3. Your answer should include the following
   - Nutrients, toxicants.

Check Your Progress Exercise 2

1. Your answer should include the following:
   - Clostridium botulimum, Salmonella, Staphylococcus aureus.
   - Insufficient heat processing of canned foods.
   - Poor hygienic handling of foods.
2. Your answer should include the following:
   - Hepatitis A, Norwalk, Astrovirus, Rotavirus.
   - Unhygenic handling of food after cooking.
3. Your answer should include the following:
   - Hygienic handling, chlorination, pasteurisation.

Check Your Progress Exercise 3

1. Your answer should include the following:
   - Inspection of raw materials.
   - Inspection of finished products.
   - Preparation of specifications and procedures.
   - Conformances to food regulations.
   - Waste disposal control.

1.10 SOME USEFUL BOOKS

1. Bibek, Ray (2001) Fundamentals of Food Microbiology, CRC Press, London & Washington DC.

2. Multon, J.S. (1995) Quality control for Foods and Agricultural Products, VCH Publishers, New York.

UNIT 2 QUALITY STANDARDIZATION

Structure

2.0 OBJECTIVES

After reading this unit, you should be able to:

- state the importance of food control;
- describe various national food legislations; and
- international food regulations.

2.1 INTRODUCTION

Effective national food control systems are essential to protect health and safety of the domestic consumers. They are also critical in enabling countries to assure the safety and quality of their foods entering international trade.

Especially to facilitate international trade in food and food products, international agencies have laid down regulations. The national food regulations of most countries are being harmonized with these international regulations.

2.2 NATIONAL FOOD CONTROL SYSTEMS

Some of the **objectives** of the National Food Control Systems are:

- Protecting public health by reducing the risk of food borne illness.
- Protecting consumers from unsanitary, unwholesome, mislabelled or adulterated food.

- Contributing to economic development by maintaining consumer confidence in the food system.
- Providing sound regulatory foundation for domestic and international trade in food.

The **scope** of Food Control Systems should cover all food produced, processed and marketed within the country, including imported food. Such systems should have a statutory basis and be mandatory in nature.

2.3 NATIONAL FOOD LEGISLATIONS

The laws regulating the safety and quality of food in India date back to 1899. Before 1954, states or provinces in India had their own food laws. The variations in food standards created conflicts in inter-state trade.

2.3.1 PFA Act, 1954

In 1943, Central Advisory Board was appointed which recommended for Central Legislation. Consequently in 1954, Central Legislation called "Prevention of Food Adulteration Act (PFA Act)" was enacted in the parliament, which came into effect from 1st June 1955.

Ministry of Health and Family Welfare is responsible for ensuring safe food to the consumers. The objective of the Act is to ensure supply of pure and wholesome food to the consumers and also to prevent fraud or deception. Major amendments in 1964, 1976 and 1986 have been effective in making the punishments more severe and also empowering consumers and voluntary organizations to play effective role in food safety.

Some of the salient features of the legislation include:

a) Definition of term – adulteration.

b) Powers to consumer organizations to draw legal samples and initiate legal proceedings.

c) Regulation on quality of imported foodstuff.

d) Provision of a warranty by a manufacturer, distributor or dealer to vendor.

e) Provisions for seizure and disposal of perishable foods, unfit for human consumption by local authority.

f) Appointment of an Advisory Committee called Central Committee for Food Standards (CCFS) and its sub-committees.

Adulteration

Under the PFA the food is said to be adulterated:

a) If it does not meet the specifications prescribed in Appendix - B of PFA,

b) If it contains injurious substances,

c) If any inferior or cheaper substance has been added,

d) If any constituent is abstracted from the food,

e) If article had been prepared, packed or kept under unsanitary conditions whereby it became contaminated,

f) If an article of food consists wholly or in part of any filthy, putrid, rotten, decomposed or diseased substance or otherwise is unfit for human consumption.

The PFA Rules, 1955, are divided into XVII parts. Some of the parts, which are of direct consequence to the food preservation and processing industry, are discussed.

Part VI - deals the colouring matters. It lays down the list of permitted, natural and artificial colours, as well as the maximum limit of synthetic dyes which can be used and the list of food products where the colours can be used (Rule 23 to 31).

Part VII – deals with the packing and labelling of food. It lays down the labelling provisions, the details of the label, procedure for claiming nutritional status of the product and certain restrictions on the misleading statements. It also lays down the form of labels which is to be declared on different food products. The important rule under this part is Rule 37 A which deals with the proprietary food which is the major commodity available in the market now-a-days. The important provisions under this part have been incorporated recently for declaring "Best Before Date", Non-Vegetarian & Vegetarian, Irradiation and also prohibiting misleading claims. (Rule 32 to 43).

Part VIII – provides for prohibition and regulations of sales. It prohibits the sale of certain admixtures and various products regarding their labelling and other things. It also lays down the certification of various food colours as well as food additives under ISI Certification Mark Scheme of Bureau of Indian Standards (Rule 44 to 48 C).

Part IX – deals with the condition for sale and licence. Under this Part, condition for sale and condition of licence, duration- of licence and procedure for issue of licence have been provided. Manufacturing premises, manufacturing products, Requirements for Fruit & Vegetable Products, Meat and Meat Products, Vanaspati, Solvent Extracted Edible Oils (Rule 49 to 51).

Part X – deals with the preservatives. It classifies the preservatives, lays down the quantity of various preservatives which can be used and certain restrictions on the use of some of the preservatives (Rule 52 to 55B).

Part XI – deals with the crop contaminants and naturally occurring toxic substances such as Aflatoxin, Agaric Acid, Hydrocynic Acid, and Saffrole (Rule 57A and 57B).

Part XII – deals with the use of anti-oxidants, emulsifying/ stabilizing and anti-caking agents. Under this chapter, the definition of anti-oxidants, emulsifying and stabilizing agents along with maximum limit of these additives, which can be used in food products, have been prescribed. (Rule 58 to 62B).

Part XIII – deals with the flavouring agents and related substances.

Part XIV – deals with the use of insecticides and pesticides in food products. Direct use of pesticides on food is prohibited. This part also lays down the tolerance limit of various pesticides in different food products. (Rule 65).

Part XV – Solvent extracted oil and edible flour: deals with the products which are manufactured by Solvent Extraction Process. Only n-Hexane (food grade) shall be used as solvent. The limits of n-Hexane in food has been prescribed.

Part XVI – Sequestering and Buffering Agents: deals with sequestering and buffering agents and lays down the definitions of these agents. Under this part, a list of these agents has been given with the maximum level, which can be used in different food products (Rule 70 to 72).

Part XVII – deals with the Irradiation of food. Under this part, around 13 category of food products have been permitted for irradiation.

Appendix 'A': Different forms used by Food Inspectors, Public Analysts, Central Food Laboratories, have been informed. (Form I to VIII).

Appendix 'B': Under PFA Rules, specifications of various food products have been laid down which are in Appendix 'B' to the Rules. The food products which have been standardized are Carbonated Water (A.01), Baking Powder (A.02), Starchy foods (A.03), Spices & Condiments (A.05) Bean (A.06), Sweetening Agents (A.07), Coffee (A.08), Edible Fat (A.10), Milk & Milk products (A.11), Margarine (A.12), Tea (A.14), salt (A.15), Fruits and Vegetable products (A.16), Edible Oils (A.17), Cereals & Cereal products (A.18), Vanaspati (A.19), Vinegar (A.20), Catechu (A.21), Gelatin (A.22), Sweets and Confectionary (A.25), Food colours (A.26), Silver leaf (A.27), Groundnut Kernel (A.28), Alcoholic Beverages (A.29), Pan Masala (A.30), fat Spread (A.31), Mineral Water (A.32), Packaged Drinking Water (A.33) and Packed Meat and Meat products (A.34).

Under Appendix 'B' most of the foods, which are in market generally, are covered, but still there are large number of foods, which are not standardized. Such products are treated as proprietary food under Rule 37A.

From the foregoing, it is proved that the Food Laws in India are comprehensive covering all aspects.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why national food legislation is required?

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2. List the common food hazards.

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3. List the salient features of the PFA Act.

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4. What is an adulterated food under the PFA Act?

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2.3.2 Fruit Product Order, 1955

The Fruit Product Control Order was issued in 1946. Subsequently, this Order was brought under Essential Commodities Act, 1955 and thereafter this Order is known as Fruit Products Order, 1955.

The Ministry of Food Processing Industries, Govt. of India, administrates this Order. The Order provides for compulsory licensing for manufacturing fruit and vegetable products.

To ensure hygienic conditions of the manufacturing unit and its workers, the Order lays down the hygienic and sanitary requirements for setting up factories for the manufacture of fruit and vegetable products. It is also essential to have a laboratory in the manufacturing unit to test the quality and specification of the products.

Under this Order, specifications of various fruit and vegetable products have been laid down. These specifications are at least equal to the specifications laid down under PFA Act if not higher.

2.3.3 Vegetable Oil Products (Regulation) Order, 1998

The Vegetable Oil Products (Regulation) Order has been issued in 1998 in super session of Vegetable Oil Product Control Order, 1947 which was issued under Section 3 of Essential Supplies Act, 1946, in super session of Vegetable Oil Products Control Order, 1946 which was in existence at that time. Later on, after passing the Essential Commodities Act, 1955, the Vegetable Oil Product Order was adopted under Essential Commodities Act. This Order is implemented by Directorate of Vanaspati, Vegetable Oils & Fats, Ministry of Food & Civil Supplies. Govt. of India. Products covered under this Order are Vegetable Oils, Vanaspati, Margarine and Bakery & Shortening. The Order provides for compulsory licensing for manufacturing units. The specifications of the products, namely, Vanaspati, Margarine and Bakery & Shortening have been laid down under this Order.

2.3.4 Solvent Extracted Oil, De-Oiled Meal and Edible Flour (Control) Order, 1967

This Order issued under Section 3 of Essential Commodities Act, 1955, for controlling the production and distribution of Oils, De-oiled Meal and Edible Flour, which are obtained by the methods of solvent extraction. This Order provides for compulsory licensing of manufacturing units. The licence to such units under Rule 50 of the PFA Rules is exempted. The specifications of the edible oils produced by solvent extraction method have been laid down under the said Order. The packing & labelling conditions of such oils are also laid down but these oils shall conform to the specifications laid down under item A.17 of Appendix ‘A' of the PFA Rules.

2.3.5 Meat Product Control Order, 1973 (Ministry of Rural Areas and Employment)

This order has been issued under the essential commodity act, 1955. Licensing under PFA Rules, 1955 are exempted for those industries which manufacture meat and meat products. Quality and safety parameters have been prescribed for meat and meat products under this order. The quality and safety parameters have now been provided under PFA Rule, 1955 for these products also. However, under this order, requirement of Heavy metals and Pesticide Residues have been prescribed. Additionally, the list of preservatives, sequestering and buffering agents for use in these products have also been provided. This order emphasizes for the hygienic conditions of the plant machinery and personnel. Agricultural Marketing Advisor to Government of India is implementing this order.

2.3.6 Edible Oil Packaging (Development and Regulation) Order, 1998

Ministry of Consumer Affairs has issued this order in 1998 during the period of dropsy in India. In 1998, some mustard oils were found to be adulterated with argemone oil. To control the quality of edible vegetable oils the above order was issued. The main provision of this order are as follows:

- All edible vegetable oils shall be sold only in packed conditions.
- All the edible vegetable oils shall be packed only after testing by the manufacturers.

- All the edible oils shall meet the requirement prescribed under PFA Rules, 1955 for such oils.
- The methods of analysis to be used are the same, which have been prescribed in the manual prescribed by Directorate General of Health Services.
- All the manufacturers will have to register themselves with the local civil supply departments and shall file the returns as prescribed under that order.

2.3.7 Milk and Milk Product Order, 1992, Ministry of Agriculture

This order was issued under the essential commodities act, 1955. The Ministry of Agriculture, Department of Animal Husbandry and Dairying, Government of India are implementing this order. Under this order, conditions for registration and its renewal have been prescribed. The concerned inspector assesses the hygienic conditions of the premises and the quantity of such product being processed. Quality and safety parameters for milk and milk products have not been prescribed under this order meaning thereby that all the milk and milk products shall meet the Standards prescribed under PFA Rule, 1955. The main aim of this order is to control the collection of milk and production of milk products in addition to hygienic requirement of the plant, machinery and personnel.

2.3.8 Standard of Weights and Measures Act, 1976

The Standard of Weights and Measures Act, 1976 was enacted to establish standards of weights and measures, to regulate inter-state trade or commerce in weights, measures and other goods which are sold or distributed by weight, measure or number, and to provide for matters connected therewith or incidental thereto. The Act extends to the whole of India.

When commodities are sold or distributed in packaged form in the course of inter-State trade or commerce, it is essential that every package must have:

- Plain and conspicuous declaration thereon showing the identity of the commodity in the package,
- The net quantity in terms of the standard units of weights and measures and if in nos., the accurate number therein,
- The unit sale price of the commodity and the sale price of that particular package of that commodity.
- The names of the manufacturer, and also of the packer or distributor, should also be mentioned on the package.

In this regard the Packaged Commodities Rules were framed in 1977. These Rules extend to the whole of India and apply to commodities in the packaged form which are, or are intended or likely to be sold, distributed or delivered or offered or displayed for sale, distribution or delivery or which are stored for sale, or for distribution or delivery in the course of inter-state trade and commerce.

2.3.9 Export (Quality Control and Inspection) Act, 1963

The Export Inspection Council (EIC) was set up by the Government of India Export (Quality Control and Inspection) Act, 1963 (22 of 1963), in order to ensure sound development of export trade of India through Quality Control and Inspection and for matters connected thereof. The Council, constituted by the Central Government, is the apex body and has powers to constitute specialist committees to assist it in discharge of its functions. Accordingly, the Council has constituted Administrative Committee to advise it on administrative matters and a Technical Committee to advise it on technical matters.

Besides its advisory role, the Export Inspection Council, also exercises technical and administrative control over the five Export Inspection Agencies (EIAs) at Chennai, Delhi, Kochi, Kolkata and Mumbai. EIA's were established by the Ministry of Commerce, Government of India, under for the purpose of implementing the various measures and policies formulated by the Export Inspection Council of India.

Further, under the Export (Quality Control and Inspection) Act, 1963 following units have been set-up by the Ministry of Commerce for ensuring promotion and quality control of export of food item:

- Export inspection Council. (E.I.C.);
- Agricultural and Processed Food Export Development Authority (APEDA);
- Spices Board;
- Coffee Board;
- Tea Board;
- Marine Products Export Development Authority (MPEDA).

Pre-shipment inspection and analysis is carried out in order to ensure that exported items conform to the quality prescribed by the importing countries and do not pose any health hazard.

In case of some of the food article like spices and condiments, fruit products, and meat products, the system of compulsory certification has been introduced.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe briefly the provisions of Fruit Products Order, 1955.

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2. Which are the important provisions of 'Solvent extracted oil, De-oiled Meal & Edible Flour (Control) Order, 1967 and 'Standard Weights & Measures Act, 1976?

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In addition to the above legislations, there are a few voluntary based product certification agencies in the country viz. BIS, and Agmark.

2.3.10 Bureau of Indian Standards Act, 1986

Bureau of Indian Standards has been constituted under an act of Parliament i.e. BIS Act, 1986, which deals with standardization of various consumer goods including food products.

The organization also runs a voluntary certification scheme known as "ISI Mark for certification of processed food items". The authorities after inspection and ensuring that the manufacturers have got the necessary technical know-how, hygienic conditions and other facilities available, grant them a certificate to use ISI mark on their products. Under the provisions of PFA Act, it has been made compulsory that commonly used food additives permitted for use in specified items of food, condensed milk, different categories of Milk Powder, Infant milk substitute, Infant food, packaged drinking water and mineral water and some food additives will be sold only under ISI Certification Mark.

2.3.11 Agmark Grading and Marking Act and Rules, 1937

Under the Grading and Marking Act the Directorate of Marketing and Inspection was constituted in the Ministry of Rural areas and Employment, which operates a voluntary scheme of certification of agricultural products (raw and processed) for safeguarding the health of consumers under 'Agmark'. An approved chemist tests each batch of consignment before certification is granted. The PFA Rules, 1955 provide compulsory Agmark certification of Blended Oils, *Carbia callosa* and Honey dew; Kangra tea; Ghee moving from one state to another; Til Oil produced in Tripura, Assam and West Bengal. Further, certain food items meant for export have been brought under compulsory Agmark certification viz. walnuts, black pepper, cardamom, chillies, ginger and turmeric etc.

The Directorate of Marketing and Inspection has 21 laboratories and 50 sub offices spread all over the country. The Central Agmark Laboratory at Nagpur carries out research and development work in this field.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Name two voluntary certification agencies.

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2. Explain 'ISI mark and 'Agmark'.

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2.4 FOOD REGULATIONS FOR INTERNATIONAL ORGANIZATIONS

Since ancient times authorities all over the world made attempts to codify the tools to protect the consumers from dishonest practices in sale of foods. With development in food science, food chemistry and consumer awareness, national governments and international organizations stepped into food and health area, to protect consumers from fraud and to provide clean, wholesome, nutritious and safe food to all.

2.4.1 Codex Alimentarius Commission (CAC)

An UN resolution passed in 1963 to establish Joint FAO / WHO programme paved way for CAC's Food Standard Programme.

During the past 4 decades, all aspects of foods – processing, labelling, packaging, nutrition, consumer health and fair practices in trade have come under the commission's scrutiny.

So far Codex has:

- Formulated standards for 237 food commodities.
- Formulated 41 codes of hygienic practices.

- Evaluated 185 pesticides.
- Prescribed limits for contaminants.
- Developed guidelines for 25 contaminants.
- Evaluated 1005 food additives.
- Evaluated 54 veterinary drugs.

Codex India is the National Codex Contact Point (NCCP) for India, it is located at the Directorate General of Health Services, Ministry of Health and Family Welfare, New Delhi. It coordinates and promotes Codex activities in India.

2.4.2 International Organization for Standardization (ISO)

The objective of ISO is to promote the development of standards in the world with a view to facilitate international exchange of goods and services, and to develop mutual co-operation in the sphere of intellectual, scientific, technological and economic activity. Other functions of ISO are:

- Helps in Harmonization of food standards throughout the world.
- Facilitates exchange of scientific knowledge between countries.
- Promotes economic development.
- Promotes exchange of goods.
- Promotes free and fair global trading with strategic partnership with WTO.
- Standards help to revise levels of quality, safety, reliability, efficient, compatibility and inter-exchangeability.
- Safeguards consumers and users.
- Global exchange of goods and services incorporating rationality, practical applicability, environmental protection, safeguards safety and health, and provides equal opportunities in world trade.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the role of Codex Alimentarius Commission.

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2.5 LET US SUM UP

Food quality and safety are of paramount importance. Each country has evolved its own food legislations to safeguard the health and well being of its citizens and also promotes its international trade in raw and processed foods. India has enacted the food legislation called the Prevention of Food Adulteration Act (PFA). Besides PFA, few other Acts and Orders of the Government of India deal with specific food commodities. Certification of quality by BIS and Agmark also ensures food product and fresh produce quality.

International food standards like CODEX play very important role in international trade of fresh and processed foods. National food standards are being harmonized with the international standards to further strengthen world trade in food and food products.

2.6 KEY WORDS

PFA	:	Prevention of Food Adulteration Act, 1954.
FPO	:	Fruit Product Order, 1955.
ISI	:	Indian Standards Institution.
BIS	:	Bureau of Indian Standards.
ISO	:	International Organization for Standardization.

2.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Food borne illnesses
   - Adulterated food
   - Domestic and international trade
2. Your answer should include the following points:
   - Microbial
   - Pesticide residues
   - Misuse of food additives
   - Metals, toxins
3. Your answer should include the following points:
   - Definition of adulteration
   - Public analysts and food inspectors
   - Consumer organizations, legal proceedings
   - Imported foodstuffs
   - Warranty
   - Trial and punishment

4. Your answer should include the following points:

   - Not meeting specifications
   - Containing injurious substances
   - Addition of cheaper, inferior substances
   - Food prepared under insanitary conditions
   - Unfit for human consumption

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Ministry of Food Processing Industries
   - Hygienic and sanitary conditions in factories
   - Specifications of fruits and vegetable products
   - Compulsory licensing

2. Your answer should include the following points:

   - Compulsory licensing solvent extraction units
   - Specifications of oils
   - Packaging and labelling
   - Quality and safety of meat products
   - Heavy metal and pesticide residues
   - Preservatives, sequestering and buffering agents

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - FAO/ WHO
   - International food standards
   - Standards for food commodities
   - Codes of hygienic practices
   - Limits for food contaminants
   - Food additives

2. Your answer should include the following points:

   - ISI mark is covered under Bureau of Indian Standards Act, 1986
   - Certification Mark of quality
   - Standardization of goods including food products
   - To ensure production of food products under hygienic conditions
   - Under PFA Act food additives, specific food and drinking water and mineral water will be sold under ISI certification Mark
   - Agmark a voluntary scheme of certification of agricultural produce
   - It is operated under Agmark Grading and Marketing Act and Rules, 1937
   - Agmark ensure for safeguarding the health of consumers
   - Blended oils, Ghee, Til oil, etc. are sold under Agmark certification

Check Your Progress Exercise 4

1. Your answer should include the following points:

   - Codex Alimentarius Commission (CAC) operates under Joint FAO/WHO Programme
   - It scrutinized Food Standard Programme
   - Formulate standards for food commodities, hygienic practices, pesticides residues, food additives etc.

2.8 SOME USEFUL BOOKS

1. Prevention of Food Adulteration Act (1954) 24th Edition, 2003, Easterb Book Company, Lucknow (www.nohfw.nic.in/pfa).

2. Fruit Products Order (1955) All India Food Preserver's Association, New Delhi. (www.mofpi.nic.in).

UNIT 3 FOOD SAFETY MANAGEMENT

Structure

3.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the importance of food safety and understand different food safety programmes like:
  - good manufacturing practices;
  - hazards analysis and critical control points;
  - international organization for standardisation; and
  - total quality management.

3.1 INTRODUCTION

The demand for fresh and processed foods throughout the world is increasing steadily along with the increasing population. This has necessitated bulk handling, processing, storage and distribution of foods. There is every possibility that some times these operations are carried out defectively introducing food hazards. The developments in food science have opened up the possibility of using numerous food additives capable of preserving and modifying foods to the requirements of the consumer. However, inadvertent use of these additives can also result in food hazards.

The conventional quality control methods in which the quality of the fresh or processed foods is tested just before distribution, though has been very useful in ensuring food safety, is a post-mortem exercise. This means that if the food at the distribution stage is found to be defective, there is no way to salvage it. In order to overcome this drawback, new Food Safety Management Systems have evolved. These systems, besides ensuring food safety, also enable production of food products with no or minimum defects. You will be learning the basic aspects of some of these systems in this unit.

3.2 FOOD SAFETY

Food is comprised of an array of chemicals, namely; proteins, fat, carbohydrates, vitamins, minerals and fibre which are required to sustain life. These constituents of food have nutritional value. We all expect food to be nutritious, wholesome, and safe. **Absolute safe food** is the one, which will not cause any damage or harm. However, our food is subject to contamination and therefore, **relative food-safety** can be defined as the practical certainty that injury or damage will not result from a food used in a **reasonable** and customary manner and **quantity**.

Food safety can be understood in a better way if we use two basic concepts – Toxicity and Hazard. Toxicity is the capacity of a substance to produce harm or injury. Hazard is the relative probability that harm or injury will result when the substance is used in a proposed manner and quantity.

3.2.1 Food Hazards

You have already learned some aspects of food hazards in an earlier unit. A hazard is a biological, chemical or physical agent in a food, which has the potential to cause harm or injury to the health.

Biological hazards include pathogenic bacteria, fungus, virus and parasites and toxins elaborated by these organisms. They may cause infections and produce toxins.

Chemical hazards include naturally occurring toxicants such as trypsin inhibitor, solanins, haemagglutinins, phytates, cyanogenic glycosides and alkaloids; heavy metals such as lead, cadmium, arsenic and mercury; pesticide residues like DDT, malathion, parathion, endosulfan, etc. Chemical hazards can also be mycotoxins like aflatoxins developed on nuts and corns, veterinary drug residues and also unapproved food additives or additives added in excess.

Physical hazards include extraneous matter such as stones, glass fragments, dirt, metal bits, etc.

3.2.2 Importance of Safe Foods

A safe food ensures prevention of food borne diseases, and provides nutrition and good quality to the consumer. It also promotes international trade and stimulates economic development.

Maintaining food safety and quality is essential in the entire chain of food production ranging from raw agricultural commodity at farm level; primary food processing at the farm, dairy, abattoir (slaughter house) and grain mills; secondary food processing level such as canning, freezing, drying and brewing and packing; food distribution both at national and international level; food retailing and food catering and domestic food preparation.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between absolute and relative food safety.

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2. Explain different types of food hazards.

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3.3 FOOD SAFETY PROGRAMMES

Consumer confidence in the safety and quality of the food supply is an important requirement. A successful safety programme involves a shared responsibility among Food Industries, Government and Consumer. Food Safety Management has progressed rapidly in recent years. The international agencies like Food and Agriculture Organization (FAO) and World Health Organization (WHO), Codex Alimentarius Commission (CAC) – a joint FAO / WHO programme, and International Organization for Standardization (ISO) are playing vital role in the safety management of foods.

3.3.1 Good Manufacturing Practices (GMP)

Good Manufacturing Practices can achieve food safety. Good Manufacturing Practices in manufacturing and packing are pre-requisites for acceptable food safety. GMPs are essential for the manufacture and distribution of foods that are safe from microbiological, chemical, and physical hazards. It is essential that the food industry manage a comprehensive programme that evaluates, identifies, and controls potential hazards at every step in the production, development and manufacturing environment.

Requirements for GMP for Food Industry

Good Manufacturing Practices are prescribed to ensure that:

- Factory is at proper location.
- Factory has right layout and building design.
- Raw materials used in the products are of right specifications.
- Manufacturing processes are properly prescribed and implemented to ensure right quality finished products.
- Adequate quality standards are in place.
- All critical control points are specified by hazard analysis.
- Finished products are released for market only after prescribed quality analysis.
- These are stored and transported in hygienic manner.
- All market returns are properly stored, analyzed, reworked or disposed off with proper procedure.
- Traceability procedure is in place.

To achieve the above objectives each manufacturer ensures that each step is properly followed with detail procedures in place.

3.3.2 Hazard Analysis and Critical Control Point (HACCP) System

Hazard Analysis Critical Control Point (HACCP) system is a prevention system. Here the focus for control is on the manufacturing process. Various monitoring and control methods are applied to reduce or eliminate the possibility of contamination. HACCP is a worldwide – recognized systematic and preventive approach that addresses biological, chemical and physical hazards through anticipation and prevention during manufacturing process.

Important Definitions

Hazard: the potential to cause permanent or temporary injury to a consumer

Severity: The magnitude of consequences resulting from a hazard.

Risk: An estimate of the probability of a hazard occurring.

Control: Actions taken or conditions applied either to reduce to acceptable levels or to eliminate a hazard.

Critical Control Point: A point in the food manufacturing, distribution and use chain where control is exercised.

Benefits of HACCP Certification

- It will reduce the risk of customers being food poisoned.
- It will increase quality of the product.
- It will ensure compliance with the law.
- It will reduce reliance on end-product inspection and testing.

Principles of HACCP

Food Safety Management System by HACCP has seven principles:

1. Identify the hazards:

   Look at each step (e.g., purchasing, delivery, storage, preparation, cooking, serving and display, etc.) in your operation and identify what can go wrong.

2. Determine the Critical Control Points (CCPs):

   Identify the points in your operation that ensures control of hazards, e.g., adequate cooking will kill E.coli and other pathogens.

3. Establish Critical Limits:

   Set limits to enable you to identify when a CCP is out of control, e.g., the critical limit for hot holding of cooked foods is +63°C.

4. Establish a system to monitor control of CCP you should decide

   - Who should check that the critical limit has not been exceeded,
   - How often the check should be done, and
   - What exactly the check involves.

5. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.

   When monitoring indicates that a CCP is not under control, corrective action must be taken, e.g.

   - Discard the food when it is past the use before a particular date

6. Establish procedures for verification to confirm the HACCP system is working effectively. Review and correct the system periodically and whenever you make changes to your operations, e.g.,

   - Change of recipe, installation of new equipment, etc.

7. Establish documentation concerning all procedures and records appropriate to these principles and their application.

   For the successful implementation of the system, appropriate documentations and records must be kept and be readily available, e.g., - Temperature record sheets.

A safety food management system based on these principles will enable hazards to be identified and controlled before they threaten the safety of the food served to customers and damage the reputation.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. List the requirements of GMP for food industry.

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2. Define 'Hazard' and 'Critical Control Point'.

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3. List the benefits of HACCP certification.

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4. List the principles of HACCP.

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3.3.3 International Organization for Standardization (ISO)

The global market place provides opportunities for food processors and also creates concerns for consumers. International standards provide tools to reduce consumer concerns and provide tools for the promotion of food trade.

The International Organization for Standardization (ISO) is a non-governmental organization located in Geneva, Switzerland. It was formed in 1947 to develop a common set of manufacturing and trade and standards to facilitate international trade. ISO is made up of 138 nations.

ISO: 9000 – 1994 is an international standard directed at the quality management process of an organization; it included the group of standards ISO-9001, ISO-9003 and ISO-9004.

ISO-9001 standard is a management tool that focuses on meeting the customer's needs and expectations; every step in achieving the quality is documented. The documented system defines policies, objectives, and expected performance.

"Quality Management" refers to "all activities of the overall management function that determines the quality policy, objectives and responsibilities of the quality system".

Quality System is "organizational structure, procedures, processes and resources needed to implement the quality management. The ISO-9001: 1994 standard focuses on the existence, implementation, and effectiveness of the quality system as a whole. ISO-9001: 2000 is the latest Quality Management system.

ISO Certification is provided to the organization that has a quality management system that meets the scope of the stated standard.

Certification is the procedure by which third party gives assurance that a product, process, or service conform to specific requirements. [First party is the manufacturer and second party is the consumer. Here third party is ISO certifying agency.

Benefits of ISO Certification

Improved efficiency through both documentation and communication

- Improved consistency of manufactured items.
- Reduction in amount of re-work and non-conforming product.
- Improved customer satisfaction.
- Improved motivation and employee involvement through all levels of process.
- Reduced customer complaints.

3.3.4 Total Quality Management (TQM)

Japanese designed and built goods such as motorcars; cameras, radio and TV sets have quality and reliability. It is because Japanese industry has the ability to cope up with change and accordingly improved their management skill by adopting Total Quality Management System (TQM).

Definition: TQM is the application of quantitative methods and human resources to improve:

i) The material and services supplied,
ii) All the processes within the organization, and
iii) Degree to which the needs of the customers are met.

The TQM is a process and a journey and continuous; it is not a destination. It is a philosophy, culture and a way of doing business.

Basic Tenets of TQM

- Focus on customer satisfaction,
  - Internal customers
  - External customers
- Continuous improvements,
- Employee investment and empowerment,
- Measurement and documenting the work,
- Doing it right the first time,
- Effective communication, education and training,
- Leadership from top,
- Providing everyone with the opportunity to do their job properly.

Benefits of TQM

- Improvements in leadership qualities and more visible leadership from executives and senior managers.
- Involving personnel in decision making process.
- Increased confidence of personnel in their ability to carry out their work and to achieve targets.
- Reduction of mistakes, increased pride in work, sense of achievement for workers.
- Opportunity for self-development and self-improvement of personnel through a pro-active involvement in work.
- Opportunity to engage in creative thinking to improve product quality and work environment.
- Increased co-operation quality and work environment.
- Increased co-operation, improved teamwork and reduced conflict.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List the benefits of ISO certification.

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2. Define TQM.

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3. List the benefits of TQM.

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3.4 LET US SUM UP

Ensuring the safety of fresh and processed foods is the primary responsibility of all those involved in food handling and food processors. In order to achieve that the industry has been relying on quality control methods since long time. Although quality control has been successful in ensuring food safety and quality, it has certain drawbacks. Since it is carried out mostly at the end of the manufacturing process, retrieval of defective products is rather impossible. Rejection of defective products above a certain level adversely affects the economics of the industry. Besides, certain hazards entering the food processing operations are difficult to detect by routine analysis. Therefore, certain food safety programmes have evolved, which are capable of ensuring virtually zero levels of defects and hazards. The maim advantage of such programmes is the possibility of tracing the cause of defects easily based on the documentation, so that such recurrences can be averted.

3.5 KEY WORDS

Biological hazards : Pathogenic bacteria, fungus, virus and parasites and toxins elaborated by these organisms.

Chemical hazards : Naturally occurring toxins in foods, pesticide residues etc.

Physical hazards : Extraneous matter.

GMP : Good Manufacturing Practices.

HACCP : Hazard Analysis and Critical Control Points.

ISO : International Organization for Standardization.

TQM : Total Quality Management.

3.6 ANSWERS TO CHEECK YOUR PROGRAESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Will not cause any harm
   - Practical certainty of no harm
2. Your answer should include the following points:
   - Biological
   - Chemical
   - Physical

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - Proper factory location
   - Proper layout
   - Good raw materials
   - Quality standards
   - Quality analysis
   - Traceability
2. Your answer should include the following points:
   - Permanent or temporary injury
   - Point where control is exercised
3. Your answer should include the following points:
   - Reduce risk of food poisoning
   - Increase quality

- Compliance with law
- Reduce reliance of end product analysis

4. Your answer should include the following points:

   - Identify hazards
   - Determine CCPs
   - Critical limits
   - Corrective action
   - Verification
   - documentation

Check Your Progress 3

1. Your answer should include the following points:

   - Improved efficiency
   - Consistency
   - Deduced non conformity
   - Customer satisfaction
   - Less customer complaints

2. Your answer should include the following points:

   - Application of quantitative methods and human resources to improve
   - Materials and services supplied
   - Processes within the organization
   - Needs of customers

3. Your answer should include the following points:

   - Leadership
   - Decision making
   - Confidence
   - Sense of achievement
   - Self- development
   - Product quality
   - Team work

3.7 SOME USEFUL BOOKS

1. Gould and Gould, Total Quality Assurance for Food Industries, CTI Public. Inc., Baltimore, USA

2. Ralph, Early (1955) Guide to Quality Management Systems for Food Industry, 1st Edition, Blackie Academic Professional, London

UNIT 4 TESTING AND EVALUATION: PHYSICAL METHODS

Structure

4.0 OBJECTIVES

After reading this unit, you should be able to:

- understand colour in quantitative basis;
- describe methods for measurement of colour;
- understand viscosity, consistency and texture of foods; and
- describe methods for their measurement.

4.1 INTRODUCTION

Physical methods are used for both analysis and quality control. Analytical methods based on physical properties of food constituents are covered in detail under "Instrumental methods of analysis" in Block 7.3. In this unit, some of the important quality control parameters such as colour and Texture are described.

4.2 COLOUR

We associate colour and appearance of food with its quality. Quite often, colour plays the dominant role in assessing the overall quality of a food material. Examples are colour of fruits, vegetables, sweet meats, bakery products, ice creams and so on. Colour changes in foods during processing and storage are common. Change of the green chlorophyll colour of vegetables, browning reactions etc. is examples. In order to make foods more attractive to the consumer, natural and artificial colorants are some times added.

What is colour? Why an object is red, yellow or green? Colour is an appearance property attributable to the spectral distribution of light. Light as we commonly refer to is that part of the electromagnetic radiation to which the human eye is sensitive. The radiations of different wavelengths are called the spectrum of the radiation. The visible region of the spectrum is only a very minute part of the electromagnetic spectrum in the range of 380 to 780 nm. You will be learning more about the properties of electromagnetic radiation in the unit on 'Instrumental methods of analysis'.

As you may know, visible light can be split into its spectrum by passing it through a prism. The spectrum consists of the colours red, orange, yellow, green, blue, indigo and violet. If the light radiation striking the retina of the eye does not contain all the wavelengths of the visible spectrum, or if their intensities differ considerably, the sensation of colour results. This happens because when light radiation strikes an object, it may interact with the object in different ways depending on the nature of the object, one being absorption of the radiation. The absorption of all the wavelengths of the radiation may not take place uniformly. As a result, some wavelengths are reduced in intensity and the resultant radiation having certain dominant wavelength of the radiation is either reflected (opaque medium) or transmitted (transparent medium). The reflected or transmitted light is perceived as the colour of an object by the eye. Measurement of the transmitted radiation is the basis of spectrophotometry, which you will be learning in the next block. The measurement of the reflected light radiation is the basis of objective measurement of colour of objects like food products.

4.2.1 Factors Affecting the Colour of Objects

The perceived colour of an object in terms of its shade, brightness etc. is dependent on three major factors:

i) the chemical and physical nature of the object;
ii) the spectral power distribution in the light from the light source;
iii) the sensitivity perception system.

The colour of an object is primarily dependent on the colour producing chemical substances present in it. However, the shade, brightness and appearance of the colour can be greatly affected by its physical form. For example the colour of a whole apple is different from the crushed apple, or the colour of roasted coffee beans is different from ground coffee. In case of liquid foods, the colour varies with the depth of the solution (light path).

The perceived colour of an object is also dependent on the light illuminating it. A colour may appear dull in dim light but bright in bright light. The colour also depends on the spectral distribution of the light. The colour of an object viewed under a coloured light is different from the colour under white light.

The object properties and illumination interact to provide the stimulus for the receptor mechanism i.e. the eye and the brain system to perceive the colour. Perception of colour is unique to the individual. They change with colour vision abilities. Approximately 8% of the population perceive colour in a different way from the remainder. The other 92% of the population do not perceive colour in exactly the same way.

The above factors make it necessary to evolve an agreed terminology for colour description and measurement. Colour measurement implies expressing the above concepts in numerical dimensions.

4.2.2 Approaches to Colour Measurement

Two approaches are possible for colour measurement. The simplest method is to use a numerical index, which defines a colour adequately for specific purposes and enables comparison. This could be termed '**colour comparison'.** Obviously, this method does not specify all the attributes of a colour, which is required for several purposes. The second approach is to quantitatively specify the colour by determining the recognizable attributes of the colour.

4.2.3 Colour Matching

The eye has tremendous capacity to discriminate colours. However the capacity of the brain for remembering them is poor. For example, the brain cannot exactly remember the colour of a fruit of a previous year. During storage studies of food products, its colour changes and the original sample with out the colour change may not be available for comparison. Therefore, matching the colour with a colour order system is followed. Colour dictionaries (atlases), disc colorimeters and tintometers are usually used for the purpose.

Colour dictionaries: Colour dictionaries usually consist of sets of colour charts grouped into different hues. In order to get reliable data, matching of colours should be done by individuals with normal colour vision using standard viewing and lighting conditions. One of the most popular colour atlases used for horticultural crops is the **Royal Horticultural Society (RHS) Charts.**

Another colour atlas, which used to be widely quoted in food industry, is the **Munsell System.** In the Munsell System, colour dimensions are Hue (H), Value (V) and Chroma (C). The Figure 4.1 below is a sketch of the Munsell colour solid.

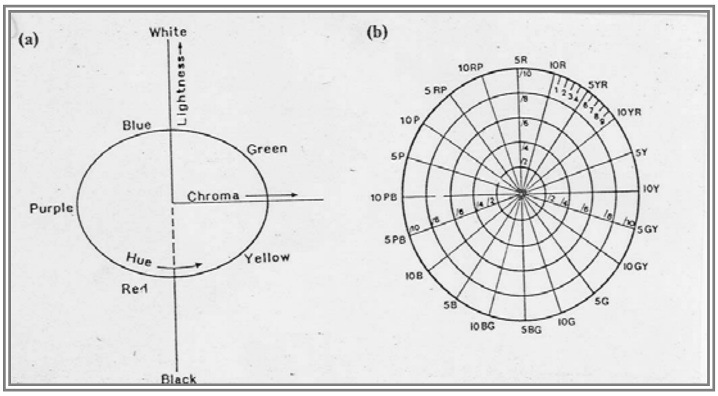


Figure 4.1: The Munsell colour system: a) dimensions of the Munsell colour system solid; b) organization of Hue and Chroma in the Munsell System solid.

The hue circle consists of ten major hues, each divided into ten equally spaced steps. The central achromatic Value (lightness) axis consists of ten equal steps, extending from ideal black = 0 to ideal white=10. The distance from this axis indicates an increase in Chroma that is an increase in hue content, and departure from grey. The Chroma is zero at the achromatic axis, and increases in visually equal steps to /10, /12, /14 or greater for particularly saturated colours. The Munsell atlas consists of pages of coloured chips. The chips are arranged so that the vertical axis of the pages represents an increase in V, the horizontal axis an increase in C. The Munsell description of a yellow-red colour of hue 3YR, Value 5/, and Chroma 6/ is denoted as 3YR 5/6.

Munsell system is some times used in conjunction with Disc colorimeters like the Macbeth- Munsell Disc colorimeter. In the Disc colorimeter, rapid spinning mixes two or more colours in the form of interleaved discs. The resultant hue is the average hue of the sample, which is useful in certain situations like colour of vegetables or homogenised samples, but not for comparing non-uniform colour surfaces like the colour of fruits like apple.

Tintometers: The Lovibond Tintometer used to be widely used in the food industry for a long time before more refined instruments became available. It is still in use for specific applications. The instrument is provided with sets of red, yellow and blue glass slides as permanent standards. The slides form an evenly graded series from very light tints (0) to deep colours (20), numbered according to their depth of colour. The three series are so related that when three slides of equal value are combined and viewed against white, they appear grey or neutral in colour. With the help if an optical system in the instrument, the illuminated sample is made to occupy half the field of view while the other half receives reflected light from a standard white surface, which passes through the selected coloured glass. When the colour is matched, it is specified by the values of red, yellow and blue slides required as for example 14.0 R + 6.0 Y + 1.0 B.

4.2.4 Quantitative Measurement of Colour

A complete specification of colour requires measurement of three attributes of colour.

i) **Hue**: the kind of colour, red, blue or green.

ii) **Saturation**: the depth or strength of the hue or the extent to which the pure hue is mixed with white.

iii) **Lightness**: the extent to which the hue is diluted with black. It is associated with brightness of the hue.

The International Commission on Illumination (CIE: *Commission Internationale de l'Eclairage*, 1931) adopted a set of standards, which has made it possible to define the colour in absolute terms. The system is rather elborate and hence only some salient points are explained here.

4.2.5 The CIE System

The CIE system is based on the principle that any colour can be matched exactly by a suitable mixture of only three colours selected from the red or amber (R), green (G) and blue (B) parts of the light spectrum. The three colours are called "**primaries**" and their relative amounts required to match a colour are called "**tristimulus**" values of the colour. This postulate has been confirmed by colour matching using additive mixing of monochromatic lights of wavelength 650 nm (R), 530 nm (G), and 460 nm (B) to obtain colour matches by observers with normal colour vision called the standard observer. The amount C of each colour (C) is matched using amounts of R, G, and B of each particular stimulus (R), (G), and (B). i.e.

$$C\ (C) = R\ (R) + G\ (G) + B\ (B)$$

When C is unity:

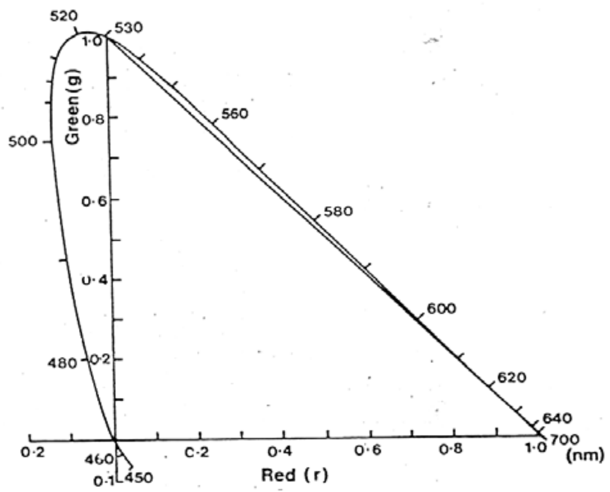
$$1.0\ \ (C) = r\ (R) + g\ (G) + b\ (B)$$

where:

$$r = \frac{R}{R+G+B}, \quad g = \frac{G}{R+G+B}, \quad b = \frac{B}{R+G+B}$$

Where: r, g and b are chromaticity coordinates of the colour i.e., r+g+b = 1

Therefore, if any two of r, g and b are specified, the third can be calculated. Hence, the results can be shown in the form of the two-dimensional **chromaticity diagram** in which r and g are usually plotted as x and y axis (Figure below).



The data from Fig. 7.3 plotted as a chromaticity chart. The matching stimuli used were 650, 530 and 460 nm (Wright 1969, with permission).

Figure 4.2

The spectral colours, for which the wavelengths are noted on the diagram, are shown as spectrum locus. The blue of wavelength approximately 460 nm, near one end of the locus is at the origin where r and g are zero and b = 1. The locus progresses to a wavelength of 530nm, where r is zero and g = 1 (and b is therefore zero).

It can be seen from the above figure that r, g and b have negative values. This is because the spectrum locus is convex and hence no real primaries exist which will always yield positive values. Therefore, CIE decided to use three unreal primaries (X), (Y) and (Z) so that the chromaticity coordinates x, y and z will always be positive. The modified chromaticity diagram is called the **CIE Chromaticity Chart,** which is shown below. Any given colour to be described in CIE terms can now be located in the spectrum locus by the relative distances along the x and y coordinates, representing respectively the values of X and Y.

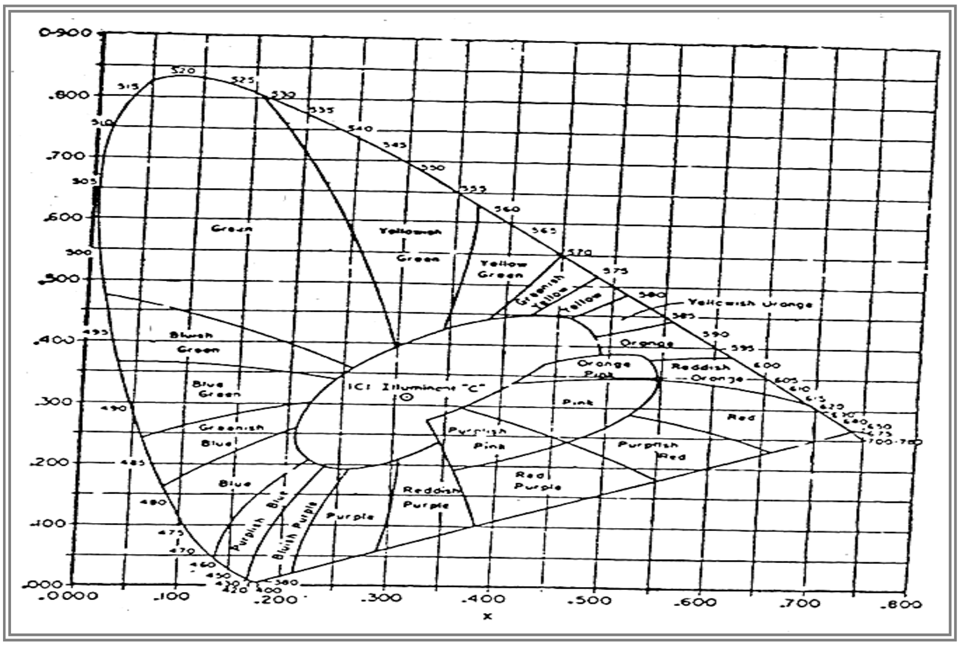


Figure 4.3: Chromaticity diagram

Having located a given colour in the Chromaticity chart from its chromaticity coordinates, it is necessary to find out its light intensity or brightness factor. This is done by assuming that all of the light energy represented by a colour is regarded as coming from Y stimulus. Therefore, the amount of Y is a direct measure of the brightness or lightness of the colour. If Y values are plotted perpendicularly to the chromaticity plane, the irregular colour solid is created within which any colour can be defined as a unique point with the CIE coordinates x, y and Y.

To determine the other visual dimensions of a colour, the colour (C) and the illuminant (S) used are marked on the chromaticity diagram as shown below.

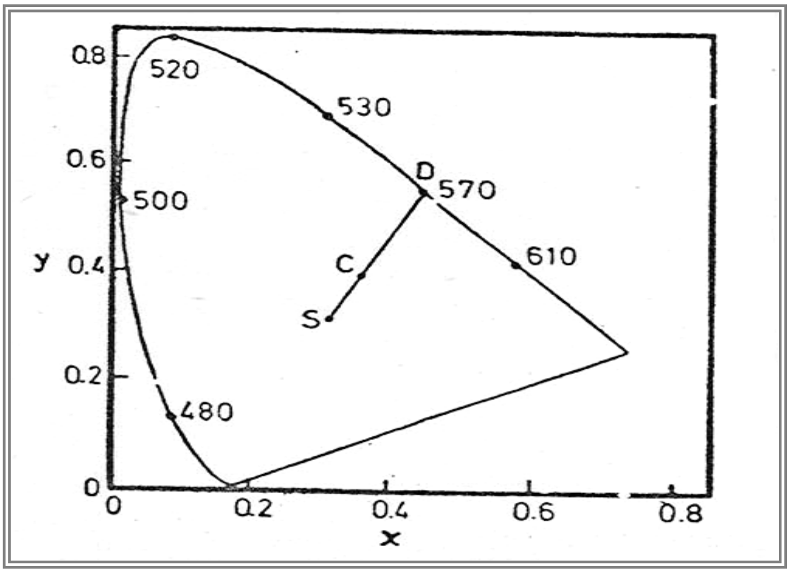


Figure 4.4: Determination of dominant wavelength and purity of colour

A line is drawn joining the two points and extrapolated to the spectrum locus (D), which is the **dominant wavelength** of the colour. Now the specification of the colour can be represented with reference of the above figure as:

Hue of the colour C is given in terms of the **dominant wavelength**

Saturation or chroma of the colour C is measured in terms of purity, which is the ratio of the distance SC to the distance SD. The ratio is usually expressed as percent.

Lightness of the colour C is given by its Y coordinate perpendicular to the chromaticity plane and is represented as Y%.

As mentioned earlier, the colour of an object is also dependent on the illuminant. Therefore, CIE system has defined three standard illuminants and their trichromatic coefficients. The illuminants are:

Illuminant A: Corresponds to the light from a gas filled tungsten lamp operated at a colour temperature of 2,856^{o}K.

Illuminant B: Corresponds to the more yellow type of average daylight, and consists of the standard illuminant in conjunction with a colour filter.

Illuminant C: Corresponds to light from the sky rather than sunlight. It consists of the illuminant A in conjunction with a different filter.

A spectrophotometric curve giving the intensities of light at different wavelengths of the visible region gives a complete specification of the colour. This can be calculated from the spectral data, which is quite tedious and hence not given here. This is made easy in the present day spectrophotometers, which automatically records the spectral curve and compute the CIE values Hue, Chroma and Lightness values.

4.2.6 Hunter Colour System and Colour Difference Meter

In the Hunter colour meter, tristimulus amber, green and blue filters together with suitable detection and measuring devices provide close approximation of the X, Y and Z functions of the CIE System. The Hunter colour space is slightly different to the CIE colour space (Figure below).

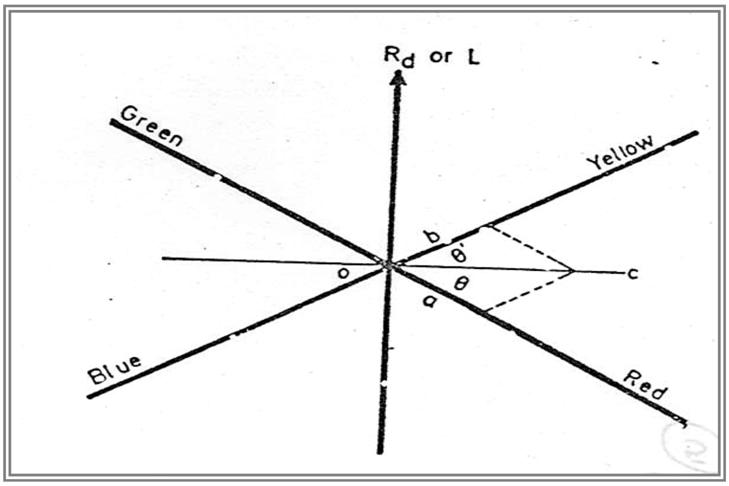


Figure 4.5: Hunter colour dimensions

The chromaticity plane is defined by dimensions *a* and *b*. The white point is at the origin. The Hunter positive *a* values indicate redness and negative *a* values greenness. The Hunter positive *b* values indicate yellowness and negative *b* values blueness. The *a* values are functions of x and y and *b* values those of Z and Y. For a particular colour C, hue or dominant wavelength is given by the ratio *a/b*. The saturation is given by the distance from the colour point C to the white point, which is $(a^2 + b^2)^{1/2}$. The Hunter R_d (diffuse reflectance) or visual lightness (L) is directly comparable to the Y of the CIE system.

Hunter values permit calculation of the colour difference (ΔE) between two colours like sample and standard colours. ΔE is given by:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}$$

The modern Hunter colour difference meters are capable of providing outputs of the various colour parameters.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is colour of an object?

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2. Which are the components of the complete specification of colour.

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3. Describe the CIE system of colour measurement.

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4. Describe the Hunter system of colour measurement.

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4.3 VICOSITY AND CONSISTANCY

The kinaesthetic attributes of food products, viz. viscosity, consistency and texture are perceived by human senses of sight, touch and mouth feel. We are able to judge whether a fluid food is thin or thick by watching how it flows, feeling it with fingers or by mouth feel. We decide the texture of fruits, vegetables etc. by finger feel. We also assess texture by biting or chewing. Obviously these assessments are subjective and tend to differ from individual to individual. Therefore, objective measurement of these quality attributes is important in quality control and product development.

Food products exist in various physical forms like thin liquids, viscous liquids, semi-solids and solids. You have observed that most of the thin liquids like beverages, milk etc. just flow out from containers. Products like tomato ketchup or sauces require some initial push (like hitting the bottom of the bottle) before they start to flow. Solids like fruits require much more pressure to compress and finally break (deformation). The study of flow and deformation of materials is called **rheology**.

Viscosity and consistency are flow properties of fluids while texture is the deformation property of solids. Obviously, the force required to initiate solid deformation is much higher than that required to initiate liquid flow. If the force required is 1.0 gravity or less, the term used is viscosity or consistency and when the force required is more than 1.0 gravity, the term used is texture.

4.3.1 Flow Behaviour of Fluids

Fluids (liquids) are classified as Newtonian or non-Newtonian depending on their flow behaviour. This can be explained easily with the help of a simple diagram.

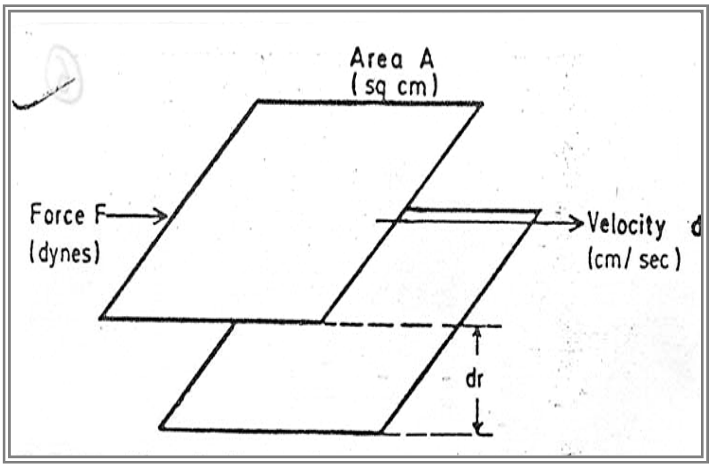


Figure 4.6: Schematic diagram illustrating the response of fluids to an imposed shearing force

Let us assume two layers of a fluid; each having an area of A cm^2 are separated by a distance dr cm. If the top layer moves parallel to the bottom layer at a velocity of du cm/sec relative to the bottom layer, a force of F dynes is required for maintaining the velocity. The velocity gradient represents the deformation, and is commonly referred to as the **shear rate**, which has the unit of per second. The shearing force per unit area (F/A) is the **shear stress** and is denoted by the symbol τ. The relationship between the shear stress and shear rate is used to define the flow properties of fluid foods.

Newton's law states that for flowing fluids, the shear stress required to maintain the flow is proportional to the shear rate.

i.e. $$F/A = \mu \frac{du}{dx}$$

Where du/dx = velocity gradient (shear rate) and μ is called the viscosity (poise) of the fluid. This is equal to:

$$\mu = \frac{F}{A} \times \frac{dx}{du}$$

$$= T \cdot \frac{|}{\gamma}$$

$$\mu = \tau / \gamma$$

where T = Shear stress
γ = Shear rate

where γ is the shear rate.

The unit of viscosity (poise) is dynes.sec/cm^2. In SI units it is equal to 0.1 N s/m^2 where N is Newton. As this unit is large, usually centipoise (cp), which is 1/100 poise, is used.

Fluids having this type of flow behaviour are called Newtonian fluids. Several fluid foods like fruit pulps, fruit juice concentrates, ketchup and sauces do not obey this law. Therefore, such fluids are called non-Newtonian fluids. For such fluids, if measurements are made at different shear rates, the ratio of shear stress to shear rate will not be constant. This ratio is called the apparent viscosity (μ_a or μ_{app}) or consistency. The consistency of non-Newtonian fluids can be expressed by the power law equation:

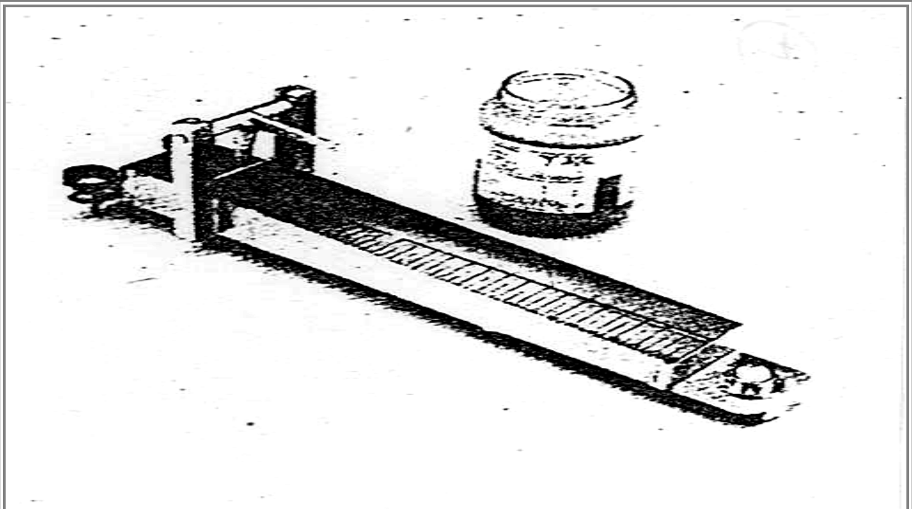
$$\tau = K (\gamma)^n + C$$

where, K = fluid consistency coefficient (dynes^n sec cm^2)
n = flow behaviour index (non dimensional)
C = yield stress (dynes / cm^2)

It can be seen from the equation that in the case of Newtonian liquids, n is equal to one and K becomes the viscosity. The constant, n for non-Newtonian liquids is a measure of the extent of departure from Newtonian behaviour, and hence is called the **flow behaviour index**. The constant K is more a measure of viscosity or consistency and is termed the fluid consistency coefficient. The viscometric parameters of non-Newtonian fluids can be determined with either capillary tube or rotational viscometers. Since determination of the parameters is very elaborate and not required for routine quality control of products, the same is not discussed here. Instead, a few viscometers and consistometers commonly used are described here.

4.3.2 Bostwick Consistometer

The Bostwick consistometer is a simple devise widely used in the industry for measuring the consistency of tomato ketchup and sauce. The instrument is based on the principle that the length of flow of the sample is proportional to its consistency.



Bostwick consistometer

Figure 4.7: Bostwick consistometer

The Bostwick consistometer (Figure above) consists of a channel with sides. It has a triggered gate on one side and a centimetre scale is itched on the floor of the channel. Before taking measurements, the consistometer is levelled by adjusting the levelling screws provided at the bottom of the instrument. Then the gate is closed by engaging the trigger release mechanism and the sample is filled in the sample holding compartment fully. The gate is released by the trigger and simultaneously a stopwatch is started. The consistency is measured after 30 sec by recording the extent of flow of the sample on calibrated scale, taking an average of the values at the centre and sides of the scale. The Bostwick consistometer readings are expressed as cm per a fixed time.

4.3.3 Brookfield Synchrolectric Viscometer

The Brookfield synchrolectric viscometer is a versatile instrument that can be used for measuring viscosity of Newtonian liquids as well as the consistency of non-Newtonian liquids. The instrument is based on measurement of resistance to rotation of a spindle immersed in the test material. The resistance is recorded in terms of torque by a calibrated spring. The dial of the instrument is graduated and the viscosity in centipoises can be read directly from the factor finder for different sizes of spindles supplied along with the instrument. As the instrument is supplied with different sizes of spindles, a wide range of viscosity measurements can be made.

The instrument is provided with a high torque motor, which is geared for different speed. Therefore, measurements can be made at different shear rates, which is required for non-Newtonian liquids. Brookfield viscometer is widely used to measure the consistency of products like tomato products, custards, dairy products, cream style corn etc.

4.4 TEXTURE

Texture is the property of food, which is associated with the sense of feel or touch experienced by fingers or the mouth. Texture of foods perceived by the mouth is a very complex phenomenon. It is perceived in three stages of ingestion of food viz. initial, masticatory and residual each consisting of different textural parameters. Therefore, objective quantitative description of the texture perceptions is quite difficult.

The physical or the mechanical textural characteristics of foods are related to the reaction of the food to stress and can be divided into parameters of hardness, brittleness, chewiness, gumminess, cohesiveness, viscosity, elasticity and adhesiveness.

In objective measurement of texture, food is subjected to compression, tension, shear and flow and the resultant deformation is measured. Measurements are made in terms of integral powers of force (m), length (l) and time (t).

All texture measuring instruments/ devices have a few essential parts. They are: I) driving mechanism to apply force, ii) probe element in contact with the sample, iii) mechanism to suitably direct the applied force, iv) sensing element, and v) read out system.

The instrumental methods of measuring the texture are based on applying force under controlled conditions. Standardisation of test cells for different types of products is crucial for getting useful data, which can be interpreted to give meaningful results. Each product in each test cell produces a characteristic force-deformation curve. Under controlled conditions of the test, the magnitude of the curve is influenced by the textural behaviour of the material tested. A typical force- deformation curve is shown in the following Figure.

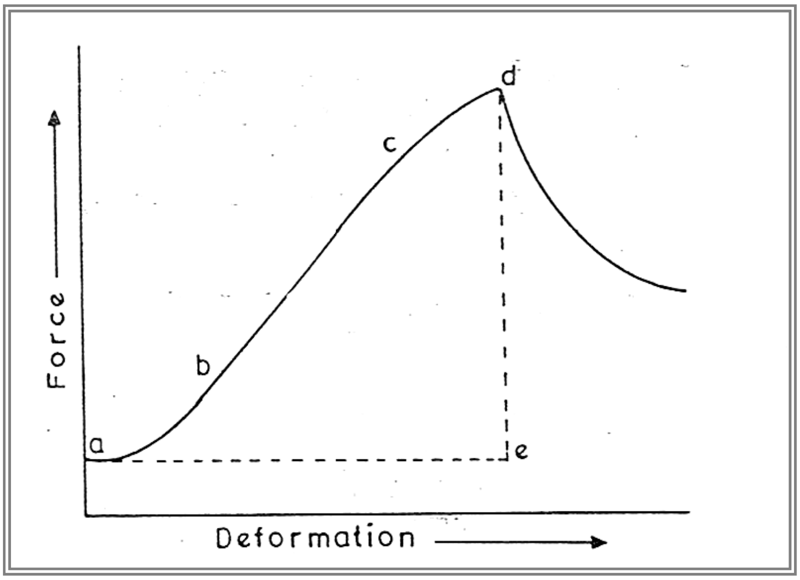


Figure 4.8

In general, the curve exhibits the following characteristics.

i) An initial non-linear portion representing packing of the cellular components of the sample under the applied stress.

ii) An approximately linear portion as the material is compressed. This slope of this portion of the curve represents the force required to attain a given deformation and hence a measure of the firmness.

iii) An abrupt change in the slope is seen when the sample begins to rupture.

iv) After the rupture point d, the force reduces.

There are different types of texture measuring instruments. Some instruments are very simple, measuring only a single mechanical textural characteristic of the product. Quite often, this is sufficient for quality control purposes. Fruit pressure tester like the Magness-Taylor pressure tester is an example of such an instrument. However, for research and development, one would like to get more extensive information on the various textural parameters of the product. This is called **texture profile analysis**.

4.4.1 Magness-Taylor Pressure Tester

This hand held instrument is widely used to determine the softening of fruits during maturation. The pressure tester uses a spring to measure applied force and a spring scale indicates the maximum test force. The tester consists of a metallic barrel inside which a spring is placed. A shaft to which a removable punch (plunger) is attached supports the spring (Figure 4.9). A small chuck at the end of the shaft ensures the fixed length of penetration. The instruments are available with springs of different force ranges to suit objects of different firmness. Each instrument is provided with punches of different diameters. The smaller diameter punches are used on firmer material and the larger on softer material.

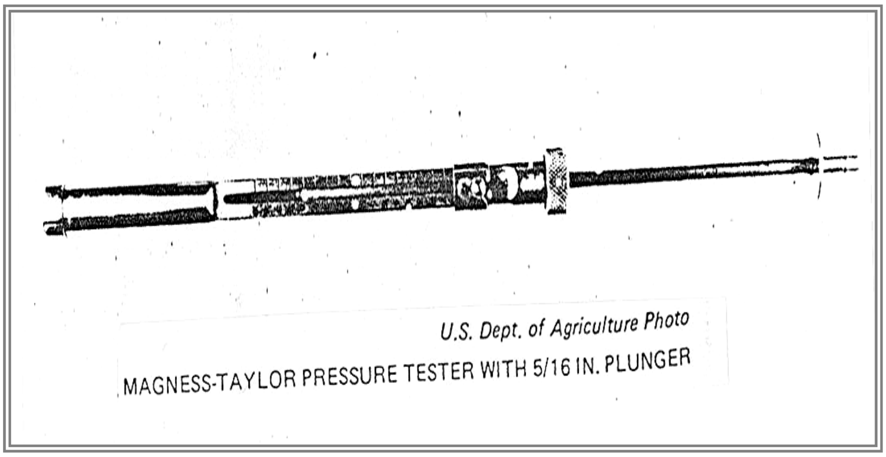


Figure 4.9

For measuring the pressure of a fruit, the plunger is held against the surface of the fruit and forced into the fruit with steady pressure applied by the hand to attain the necessary force necessary for breaking the flesh. The fruit may be peeled to overcome the interference of the skin with the action of the plunger. The force recorded on the scale indicates the maturity of the fruit. Typical range of pressure values of one variety of apples at different maturity stages is given below:

Degree of maturity/ripeness	Pressure test reading (lb) Delicious apple
Hard	17-20
Firm	14-17
Firm-ripe	11-14
Ripe	8-11

4.4.2 Instron Testing Machine

This is a versatile instrument capable of obtaining texture profiles of different types of objects. The machine consists of two parts: i) the drive mechanism, which drives a moving cross head in a vertical direction in selected speeds of 0.05 to 50 cm / min and ii) the load sensing and recording system for loads in the range of 2g to 5,000 Kg. There are different types of fixtures like flat compression plates, cylindrical compression box, assortment of needles and punches, a single star-shaped needle etc. A careful selection of the fixtures permits the measurement of different texture parameters. The instrument measures force- deformation of force- time functions. It is extensively used to measure the texture of fruits, vegetables and processed food products.

4.4.3 Measurement of Jellying Property of Pectins

Jams, jellies and marmalades are important commercial products. Pectin is commonly used to obtain the characteristic jelly like texture to the products. Therefore, the jellying quality of the pectin used determines the product quality. There are different methods for assessing the quality of pectin. Physical methods for determining jelly strength are two types. The first group of methods measure the breaking strength of jellies when they rupture after exceeding their elastic limits and the second group of methods measure jelly strength by taking into account the deformation of jellies within their elastic limits. Here one method in each group is described.

Pectinometer

The Luers-Lochmuller Pectinometer (Figure 4.10) measures the force required to pull a disc embedded in the jelly being tested upwards. The apparatus is shown below. It consists of a moving load (weight) put on one arm of a balance and the disc in the jelly attached to the other arm through a double pulley arrangement. The jelly container (corrugated) is held in a fixed position on the base of the balance (B). The disc (A) is suspended in the corrugated container (C). The jelly being tested is poured hot into the container and allowed to cool for at least one hour before the test is carried out. Now, weights are applied on the pan (W) till the jelly breaks. The corrugated sides of the container prevent slipping of the jelly in the container. The indicator (I) measures the extent of compression of the jelly. Breaking values pf jellies range from 200 to 300 g depending on the type of jelly. For quality control purposes a narrow range (± 15g) is usually fixed.

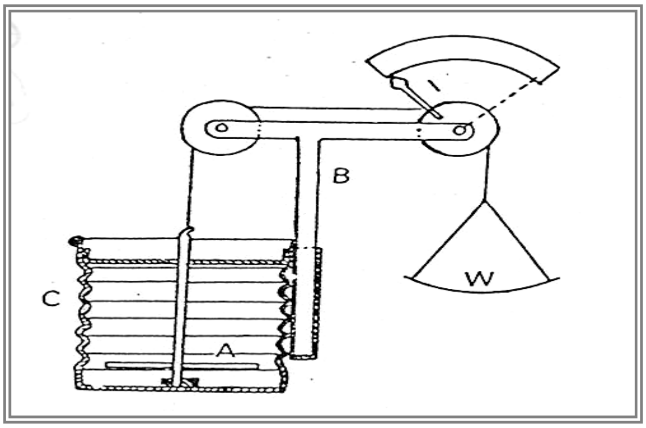


Figure 4.10: Luers and Lochmuller pectinometer

Ridgelimeter (Cox-Higby Sag Method)

Ridgelimeter measures the percentage sag or slump occurring when a test jelly is removed from its supporting container and inverted upon a glass plate. The Fig. below shows the instrument with a sample of jelly in measuring position and jelly glasses (containers). The glasses are of standard sizes of 3.125 in (79.4 mm) depth. The instrument as such has only a micrometer screw fixed on a stand. The screw has 32 threads to an inch so that one revolution moves the point by 0.03125 in., which is equal to 1% of the height of the jelly. Therefore, if the depression of the jelly as measured by the instrument is 0.03125 in. it is equal to 1% sag. For determining the jelly strength of a pectin sample, the following procedure is followed.

Weigh 48.8 g of tartaric acid in distilled water and make up to 100 ml in a volumetric flask. The quantity of pectin to be taken for the test depends on the assumed grade of the pectin. For example commercial pectin is usually supplied as 150 grade. Therefore, the assumed grade of the pectin is taken as 150. Since jellies should contain 65% sugar (TSS) i.e. 65 g sugar in 1000 g jelly, the weight of pectin to be used is 650/assumed grade of the pectin (650/150 = 4.33 g). Weigh 646 g sugar and 4.33 g pectin. Mix the weighed pectin with about 20-30 g of the weighed sugar in a dry beaker. The tare weight of a stainless steel saucepan along with a stirrer (about 1 lit. cap.) is noted and 410 ml of distilled water is taken in the pan. The pectin-sugar mix is added to the water in the pan and stirred. The pan is placed on a hot plate and heated to boil the solution. The remaining sugar is added and heating and stirring continued till the sugar dissolves completely. Heating is continued until the net weight of jelly is 1015 g. If the net weight is less, distilled water is added in slight excess and boiled down to exact weight. The entire heating time should not exceed 5-8 min. The material is allowed to stand for 1 min., any foam or scum is skimmed off and allowed to cool to 95°C (check with a thermometer) while stirring gently. Pour the hot jelly into three Ridgelimeter glasses (after fixing gummed tapes to a height of 0.5 in. above the rims) almost to overflowing, each containing 2 ml of the tartaric acid solution. After 15 min., the glasses are covered with metal lids and allowed to cool for 20-24 hr. at $25^{o} \pm 3^{o}$C.

After cooling, the lids are removed and the gummed tapes are tore off. The jelly exposing beyond the brims of the glasses is sliced off with a stretched wire. Now the jelly from one glass is removed with the help of a spatula and directly placed on to the glass plate provided along with the instrument. Start a stopwatch as the jelly is placed on the glass plate, and place the jelly directly below the micrometer screw. After exactly 2 min. bring the point of the micrometer screw just into contact with the jelly surface. Read the sag to the nearest 0.1%. Repeat the measurements with the jellies in the other two glasses also and take the average. The true grade of the pectin is calculated by multiplying the assumed grade with the corresponding factor for the measured sag provided in a tabular form along with the instrument. For example if the assumed grade is 150 and the factor for the measured sag of say 25 is 0.936, the true grade of the pectin is:

$$150 \times 0.936 = 140.4 \text{ or } 140 \text{ grade}$$

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State Newton's law and differentiate between viscosity and consistency?

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2. Describe the use of Bostwick consistometer.

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3. What is meant by the texture of a material?

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4. Describe a simple instrument to measure the pressure of a fruit.

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5. Which are the essential components of the Instron Testing machine? What is its speciality?

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6. How the Ridgelimeter is used to measure jelly strength?

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4.5 LET US SUM UP

Measurement of colour, viscosity and texture of foods is very important for quality control.

When visible white light falls on an object, some of the spectral colours of the light are partially or fully absorbed by the object. The resultant coloured radiation is reflected from a solid or semi-solid object or transmitted through a liquid object, which the eyes perceive as the colour of the object. Any colour can be matched by mixing the three primary colours viz. red, green and blue in appropriate proportions. The relative amounts of the three primary colours required to match a colour is called the Tristimulus value of the colour. This is the basis of quantitative specification of colours under the CIE system. The CIE system specifies a colour in terms of its Hue or dominant wavelength, Chroma and Lightness. Based on instrumental measurement of reflectance from an object over the entire light spectrum, it is possible to arrive at the complete specification of its colour. For routine quality control of some food products like fruits, vegetables, meat etc., simple comparison of their colour with standard colour charts gives useful data. The Hunter colour system which is related to the CIE system specifies a colour in terms of L, a, b values.

Foods can exist in the liquid, semi-solid and solid state. Liquid foods are classified as Newtonian or non-Newtonian liquids depending on their flow properties. Instruments are available to measure the flow properties of liquid foods.

Texture of solid foods is related to their reaction to stress and can be divided into parameters of hardness, brittleness, chewiness, elasticity etc. Texture of foods is determined by measuring the relationship between the applied pressure and the resultant deformation of the food material. There are simple instruments like the fruit pressure tester, which measure a single parameter of texture like the pressure required for puncturing a fruit. Such data are usually sufficient for some quality control purposes. However, more detailed texture analysis is required for many other products especially for research and product development. Such texture profile analysis is possible with instruments like the Instron Testing Machine.

Jams, jellies and marmalades are important commercial products. Quality control of such products require measurement of their jell quality. The gel quality is mainly determined by the quality of the pectin used for their preparation. The jell strength of pectin and the products are determined using simple instruments. The instruments are either based on measuring the force required to break a gel or the sag (loss of rigidity) of a gel on standing.

4.6 KEY WORDS

Hue : The colour attribute denoted by red, green, blue and so on.

Saturation : The depth or strength of hue.

Lightness : The brightness of colour.

Dominant wavelength : Wavelength of the spectrum light that, when combined in suitable proportions with the specified achromatic (colourless) light yields a match with the light considered.

Tristimulus values : The amounts of the three primary colours required to match a colour.

Rheology : Study of flow and deformation of materials.

Newtonian fluids : Fluids for which the shear stress required to maintain its flow is proportional to the shear rate.

Texture profile analysis : Determination of various texture parameters like hardness, cohesiveness, elasticity, adhesiveness, fracturability, gumminess, chewiness etc.

4.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Appearance property
   - Absorption of some spectral wavelengths
   - Reflection and transmission of light
2. Your answer should include the following points:
   - Hue
   - Saturation
   - Lightness
3. Your answer should include the following points:
   - Primary colours
   - Tristimulus values
   - Chromaticity coordinates
   - Chromaticity chart
   - Dominant wavelength
   - Standard illuminants
   - Standard observer
4. Your answer should include the following points:
   - L,a,b values
   - Colour difference

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - Ratio of shear stress to shear rate constant
   - Power law equation
   - Flow behaviour index
2. Your answer should include the following points:
   - Flow meter
   - Flow per unit time

3. Your answer should include the following points:

   - Deformation due to application of force
   - Hardness
   - Cohesiveness
   - Elasticity
   - Fracturability
   - Gumminess
   - Chewiness

4. Your answer should include the following points:

   - Magness-Taylor Pressure tester
   - Force required for puncturing

5. Your answer should include the following points:

   - Drive mechanism
   - Load sensing and recording system
   - Texture profile

6. Your answer should include the following points:

   - Standard jelly
   - Measurement of per cent sag

4.8 SOME USEFUL BOOKS

1. Kramer, A. and Twigg, B.A. (1966) Fundamentals of quality Control for the Food Industry, The AVI Publishing Co., Inc., Westport.

2. Hutchings, J.B. (1994) Food Colour and Appearance, Blackie Academic & Professional, London.

3. Owen R. Fennema (1976) Principles of food science, Part II-Physical Principles, Marcel Decker Inc.; New York.

4. Ranganna, S. (2000) Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw-Hill Publishing Co., Ltd., New Delhi.

UNIT 5 TESTING AND EVALUATION: CHEMICAL AND MICROBIOLOGICAL

Structure

5.0 OBJECTIVES

After reading this unit, you should be able to:

- describe the methods for determining crude fat, protein, pectin and tannins in food products;
- discuss various aspects of bacteriological examination of water;
- describe procedures for assessing surface sanitation; and
- explain the salient aspects of microbiological examination of spoiled canned foods.

5.1 INTRODUCTION

Analytical food chemistry deals with the methods for determining the chemical composition (quality) of foods. It employs both qualitative and quantitative methods for the purpose. A qualitative method yields information about the nature of the component and a quantitative method provides numerical information on the content of the component in the sample.

For the analysis of foods, chemical methods are more often employed even though physical methods are also proving to be very useful. The analytical methods based on the physical properties of food components are collectively known as “Instrumental Methods of Analysis’, which you will be learning in the next Block.

You will be learning and performing several analytical methods in your Practical exercises under Courses III and VII. In this unit, you will learn a few other methods, which are, either too time consuming or could not be included under the Practical exercises because they require more sophisticated facilities which are available only in specialised laboratories.

Microbiological quality of foods is equally important. A major portion of microbiological methods will be covered under Course V 'Food Microbiology". Therefore, in this Unit, only a selected few methods are discussed.

5.2 CHEMICAL ANALYSIS OF FOODS

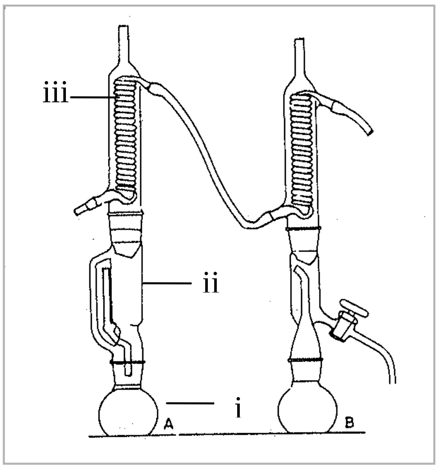
The quantitative analysis of food raw materials and their products may be classified into **proximate analysis** and **ultimate analysis**. Proximate analysis provides information on the nutritional and biochemical composition, while ultimate analysis or detailed analysis determines the content of a particular component in the food material.

The proximate analysis, especially for fruits and vegetables consists in determining the percentages of the moisture, ash, acidity, crude fat or ether extractives, protein, sugars and crude fibre. Their sum total subtracted from 100 represents primarily the amount of carbohydrates other than sugars, but includes starch, pectin, etc.

Among the above constituents, all except **crude fat, protein** and **pectin** are covered in the Practical exercises**.** Therefore, these methods are described in this unit. Tannin, which is another component of importance to fruits and vegetables, is also included here.

5.2.1 Crude Fat or Ether Extractives

As you have learnt already, food products contain water-soluble and water insoluble constituents. Among the water insoluble constituents, the ether soluble materials such as the tri- glycerides, phospholipids, sterols, essential oils, fat-soluble vitamins and pigments are very important. The first step in determining most of the individual components is extracting the food material with ether using a Soxhlet extraction apparatus (Figure 5.1). The Soxhlet extraction apparatus is an all glass simple assembly consisting of a Soxhlet flask to the top of which a Soxhlet extraction tube and a condenser are attached through standard glass joints. The Soxhlet extraction tube has provision for siphoning off the solvent used for the extraction when the level has reached a particular level.



i. Soxhelt flask
ii. Soxhelt extraction tube
iii. Condensor

Figure 5.1: Soxhlet apparatus (A) for fat extraction and (B) for solvent removal

Ether extractives are determined on samples after moisture determination (please see 'Moisture determination' under Course III Practical exercises). The dried sample is transferred to a thimble. The thimble has a tubular structure like a large test tube (having diameter and length suitable to occupy the Soxhlet extraction tube) made of cellulose filter pad. The top of the thimble is plugged with a wad of pure cotton and placed inside the Soxhlet extraction tube, which is then attached to the Soxhlet flask. About 75 ml of anhydrous ether is poured through the sample in the thimble, which percolates through the sample into the flask. The condenser is then attached and the whole assembly is placed in a heating mantle or water bath. Heat is applied just enough to boil the ether. The evaporated ether condenses and falls into the thimble containing the sample and extracts the ether soluble components. When the ether level reaches the siphon outlet level, it is siphoned off into the flask. The distillation process is allowed to continue for about 16 hours. At the end of the extraction period heating is discontinued and the thimble is removed. The ether-extracted sample is used for crude fibre estimation (please refer Practical exercise under Course III). After removing the thimble, ether is distilled off into the Soxhlet tube and poured out before the level reaches the siphoning level. Ether may be distilled off using the assembly B shown in the Fig. When the ether in the flask has reached a small volume, it is transferred into a weighed beaker with repeated rinsing with small portions of ether. The ether in the beaker is evaporated on a steam bath, dry at 100 ^{o}C for 1 hr, cooled and weighed. Crude fat is calculated by:

$$\% \text{ Crude fat} = \frac{\text{Weight of ether-soluble material}}{\text{Weight of sample}} \times 100$$

5.2.2 Protein Estimation

Protein content of food samples is usually determined by the Kjeldahl method, which is based on the determination of the amount of reduced nitrogen present in the sample. The nitrogen compounds are converted into ammonium sulphate by boiling with concentrated sulphuric acid. The ammonium sulphate formed is decomposed with sodium hydroxide and the liberated ammonia is absorbed in excess of neutral boric acid solution and titrated with standard acid.

The food sample is digested (destruction of organic matter) with conc. H_2SO_4 in a Kjeldahl flask that is a long neck round bottomed flask. To facilitate digestion and efficient conversion of all the reduced nitrogen into ammonium sulphate, small quantity of a catalyst is added. The catalyst consists of a mixture of selenium dioxide, potassium sulphate and copper sulphate in the ratio of 1:40:8. The digested and cooled sample is made up to a known volume with distilled water and an aliquot of it is distilled in a micro-Kjeldahl distillation apparatus (Figure 5.2).

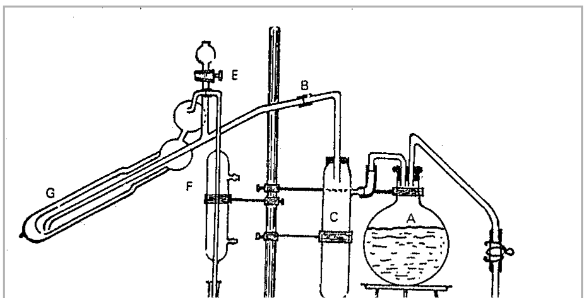


Figure 5.2: Distillation apparatus for micro-Kjeldahl determination of nitrogen
***A* steam generator, *B r*ubber tubing, *C* steam trap, *D* pinch clamp, *E* funnel, *F* condenser, *G* distillation flask**

This is a glass unit with only one short rubber tube joint (B). This rubber joint makes the unit less rigid and reduce the danger of breakage. The steam generator A is a 1-litre round-bottomed flask with a side arm for refilling. The other components of the assembly are the steam trap C, sample delivery funnel E, condenser F and sample holder for steam distillation G.

After initial cleaning of the system with steam, an aliquot of the acid digested sample and strong sodium hydroxide solution are let into the distillation flask and steam distilled. The liberated ammonia is absorbed in a known volume of dilute neutral boric acid solution containing an indicator (mixed indicator) placed below the condenser. On completion of distillation, which takes about 5 min the ammonia absorbed boric acid solution is titrated with 0.01 N HCl. From the titre value, the nitrogen content in the sample is calculated. The function of boric acid in the estimation is only to absorb the liberated ammonia and does not react chemically with it. The titration reaction is:

$$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$$

Calculations:

1000 ml 1 N HCl = 1 g mole of nitrogen = 14 g nitrogen

or 1 ml 1 N HCl = 14 mg nitrogen

Therefore

$$\%\text{ N in the sample} = \frac{\text{Titre x normality of HCl} \times 14 \times 100}{\text{Aliquot of digest taken} \times \text{weight of sample} \times 1000}$$

For calculation of protein content from the nitrogen value, a multiplication factor of 6.25 is usually used. This factor is based on the assumption that plant proteins contain 16 % nitrogen. Therefore, protein content (%) = % N × 6.25.

5.2.3 Pectin Estimation – Calcium Pectate Method

Pectin is an important constituent of fruits. Processing wastes of fruits like citrus peel and pomace, apple pomace etc. are used for commercial, production of pectin. Knowledge of the pectin content of fruits used in jam and jelly manufacture is necessary to calculate the quantity of pectin to be added. Therefore, estimation of pectin content of the raw materials is important.

Pectin extracted from plant materials is usually estimated as calcium pectate. For the estimation, the pectin sample is saponified with alkali and precipitated as calcium pectate from an acid solution by the addition of calcium chloride. The calcium pectate is washed free of chloride, dries and gravimetrically estimated.

Pectin extraction from plant materials: 50 g sample is weighed into a 1000 ml beaker and extracted with 400 ml 0.05 N HCl for 2 hr at 80 – 90^{o}C. Water lost by evaporation is frequently replaced. After cooling the suspension, it is transferred to a 500 ml volumetric flask and made up to volume with distilled water. Subsequently, it is filtered through Whatman No. 4 filter paper.

100-200 ml of the filtrate is taken in a 1 lit beaker and 250 ml distilled water is added to it. The solution is neutralized with 1 N NaOH using phenolphthalein as the indicator and allowed to stand overnight. The next day, 50 ml 1 N acetic acid is added to the solution, stirred and after 5 min, 25 ml 1 N calcium chloride solution is added with stirring. After 1 hr, the solution is boiled for 1-2 min and filtered through a previously dried and weighed (in a covered dish) filter paper circle. The precipitate in the filter paper is washed with almost boiling water till free of chloride. Presence of chloride in the filtrate is tested with silver nitrate solution. The filter paper containing calcium pectate is transferred to the covered weighing dish initially used, dried overnight at 100^{o}C, cooled in a desiccator and weighed. Calcium pectate is calculated as follows.

$$\text{\% Calcium pectate} = \frac{\text{Weight of calcium pectate} \times 500 \times 100}{\text{ml of pectin extract taken} \times \text{Wt. Of the sample}}$$

The theoretical yield of calcium pectate from pure pectinic acid is about 110%.

5.2.4 Estimation of Tannins

Tannins are widely distributed in fruits and vegetables. They belong to the general group of polyphenols called flavonoids and cinnamic acid derivatives. Tannins are responsible for the undesirable astringency of cashew apple or desirable astringency of apple and apple juice, amla etc. They are responsible for the typical taste and aroma of tea and cocoa. Polyphenols play important role in protecting ascorbic acid in some fruits and can act as a anti-oxidants. Of late, polyphenols have been shown to have several health benefits including prevention of diseases like heart attack, cancer etc.

Tannins can be estimated either by volumetric or by colorimetric method.

Volumetric method

The volumetric method of estimation of tannins is based on the oxidation of tannins by potassium permanganate.

Reagents

1. 0.04 N Potassium permanganate solution (1.40424 g $KMnO_4$ per litre).
2. Indigo carmine solution: 1.5 g indigo carmine in 1 litre water containing 50 ml conc. H_2SO_4.
3. Gelatin solution: Soak 25 g gelatin in saturated sodium chloride solution for 1 hr, heat to dissolve, cool and make up to 1 litre with saturated sodium chloride solution.
4. Acid sodium chloride solution: To 975 ml saturated sodium chloride solution, add 25 ml conc. H_2SO_4.

Procedure

An aliquot of the filtered fruit juice or extract (10 to 20 ml containing about 0.01 g of tannin) is taken in a porcelain dish and 20 ml of the indigo carmine solution is added followed by 500 ml water. From a burette the potassium permanganate solution is added to the dish with vigorous stirring until the colour becomes light green. Then the permanganate solution is added drop wise till the colour changes to bright yellow. The titre value is noted as *A*. Now, another aliquot of the juice or fruit extract (50 ml equal to 10 ml of original juice or extract) is taken in a 250 ml volumetric flask and 25 ml of the gelatin solution is added and made up to volume with the acid sodium chloride solution. It is transferred to a conical flask, a little of filter aid is added, shaken well and filtered. To 50 ml of this filtrate, 20 ml indigo carmine solution is added and titrated with the permanganate solution as done previously. The titre value is noted as *B*.

Calculations

A = Total tannin like materials

B = Non tannin materials

$A - B$ = True tannins

One ml of 0.04 N $KMnO_4$ = 0.00168 g tannin (Gallo tannic acid)

$$\% \text{ Tannin} = \frac{(A - B) \times 0.00168 \times 100}{\text{Volume of sample}}$$

Colorimetric method

The colorimetric method for estimation is based on the measurement of blue colour formed by the reduction of phosphotungstomolybdic acid by tannin like compounds in alkaline medium. The following reagents are required for the estimation.

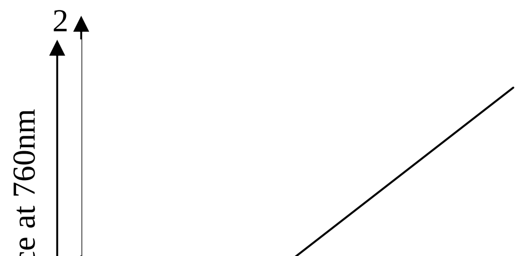
i) Folin – Dennis reagent: A mixture of 100 g of sodium tungstate ($Na_2WO_4.2H_2O$), 750 ml water and50 ml 85% phosphoric acid (H_3PO_4) is refluxed for 2 hr, cooled and diluted to 1000 ml with water.

ii) Saturated sodium carbonate solution: 35 g anhydrous sodium carbonate is dissolved in 100 ml warm (70-80^{o}C), and cooled. The clear supernatant solution is used for the estimation.

iii) Tannic acid standard solution: Dissolve 100 mg tannic acid in 1 litre water (1 ml = 0.1 mg tannic acid)

Standard curve

To a series of 100 ml volumetric flasks containing 75 ml water, 0 to 10 ml aliquots of the standard tannic acid solution is pipetted followed by 5 ml Folin-Dennis reagent and 10 ml saturated sodium carbonate solution. Make up to volume with water, mix and measure the absorbance (colour) of the solutions after 30 min in a colorimeter or spectrophotometer at 760 nm. A standard curve is prepared by plotting mg tannin in the x axis and the corresponding absorbance on the y axis.



Mg of tanin

Tannin estimation in sample

Liquid samples can be used as such. Solid samples (about 5 g) are boiled with water for 30 min, cooled and made up to a known volume.

An aliquot of the prepared sample (containing about 0.1 mg tannin) is used for colour development as in the case of standard. Note the tannin content from the standard curve and the tannin content in the sample is calculated.

Calculations

Weight of sample taken	= W ------- g
Sample extract made up to	= V ------- ml
Volume taken for colour development	= V_1 ------- ml
Tannin content in V_1 ml extract (from standard curve)	= a ------- mg

$$\text{Tannin as \% tannic acid} = \frac{a \times V \times 100}{V_1 \times W \times 1000}$$

If liquid sample is taken for estimation as such:

$$\text{Tannin as \% tannic acid} = \frac{\text{mg tannic acid in sample aliquot} \times 100}{\text{ml sample aliquot take} \times 1000}$$

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Differentiate between Proximate analysis and ultimate analysis.

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2. Describe the method for estimating the crude fat content of a food product.

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3. Describe the micro-Kjeldahl method for determination of nitrogen. How the nitrogen value is converted to protein?

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4. Describe the calcium pectate method for pectin estimation

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5. What is the importance of poly phenolic compounds in foods? Explain the volumetric method for tannin estimation.

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5.3 BACTERIOLOGICAL EXAMINATION OF WATER

Large quantities of water are used in the food processing industries for various purposes. Some of the chemical qualities of the water are discussed in another course. Bacteriological quality of water is equally or more important from the public health point of view. The main objectives of bacteriological examination of water required for the food processing industry are to check whether:

i) the water is safe for human consumption,
ii) the water requires treatment,
iii) the treatment followed is adequate.

The following parameters are usually included in the bacteriological examination of water:

i) plate count,
ii) coliform count,
iii) faecal Streptococci test.

Sampling of water: Care should be taken to collect samples of water for bacteriological examination of water. Water should be collected fresh in sterilizes glass bottles and closed properly.

5.3.1 Plate Count

Plate count or total plate count is determined by mixing a known volume of the water sample with a solidifiable culture medium and incubating it for a specified time to allow formation of visible colonies.

Requirements

i) Nutrient agar sterilized in 15 ml quantities in plugged culture tubes.

ii) Sterilized Petri dishes of 10 cm diameter.

iii) Ringer's solution (full strength): Dissolve 9 g sodium chloride, 0.42 g potassium chloride, 0.48 g calcium chloride and 0.2 g sodium bicarbonate in 1000 ml distilled water. Suitably diluted solution is sterilized at 15 psig for 20 min before use.

iv) Dilution bottle each containing 90 ml of quarter-strength Ringer's solution.

v) Sterilized 1 ml and 10 ml pipettes.

Procedure

You have already learnt sample dilution, plating etc. The agar plates are incubated at 37^{o}C for 24 ± 3 hr. After incubation, the colonies formed are counted using a colony counter. The results are expressed as **"plate count per ml at 37^{o}C in 24 hr."** Properly filtered and chlorinated water will not have total plate count in excess of 10 per ml.

5.3.2 Coliform Count

As you have learnt already, presence of coliforms in water indicates the possibility of faecal contamination and hence is strictly monitored. Coliform counts involve three tests viz. i) presumptive test, ii) confirmed test and iii) completed test.

Presumptive test: E-coli is one of the few bacteria, which is able to ferment lactose (lactose broth) with production of acid gas. Therefore, a positive test indicates 'presumptive' evidence for sewage contamination in the water sample. It is only 'presumptive' because several non-faecal bacteria also answer this test. Hence, this test must be 'confirmed'.

Confirmed test: Positive 'presumptive' test sample is plated on eosin-methylene blue (EMB) agar and incubated at 37^{o}C for 24 hr and examined. Typical E-coli colonies will have dark to black centres, button-like in appearance and will often be surrounded by a greenish metallic shine. If positive 'presumptive' sample inoculated into brilliant green lactose bile broth and incubated at 37^{o}C for 24 hr shows gas formation also, it is confirmatory evidence for the presence of E-coli.

Completed test: Completed test for E-coli is performed by transferring a typical colony from EMB agar plate to a nutrient agar slant and lactose broth tube and incubating for 24hr at 37^{o}C. A stained mount of the agar culture is examined under a microscope. A completed test for E-coli should show a pure culture of Gram-negative short rods, and gas formation in the lactose broth tube.

5.3.3 Faecal Streptococci Test

The genus Streptococcus constitutes a diverse group of cocci widely distributed in nature. Some are dangerous pathogens. Streptococci found in faeces are called faecal Streptococci or Enterococci of which Streptococcus faecalis is typical. Streptococci usually occur in pairs of ovoid cocci or in short chains. Unlike many other Streptococci, these grow well in ordinary laboratory media in the presence of bile salt. They produce deep red pin pointed colonies in MacConkey agar and ferment glucose, lactose and mannitol, producing acid but no gas. While most Streptococci are susceptible to heat (55^{o} C for 15 – 20 min), Streptococcus faecalis offers relatively high resistance destructive agents such as heat and can withstand a temperature of 60^{o} C for 30 min. In examining water for the presence of faecal Streptococci, advantage is taken of its relative heat resistance, its ability to form acid in MacConkey broth, and grow in the presence of a concentration of sodium azide sufficient to prove inhibitory to most coliform bacteria. As some anaerobic spore forming bacilli also produce acidity in sodium azide medium, a confirmatory test is also performed. In the confirmatory test, a heavy inoculum from the positive azide tubes is plated on MacConkey agar and incubated at 37^{o} C for 48 hr. The growth of minute pin pointed red colonies is a strong evidence of the presence of faecal Streptococci. On Gram-staining and observing under the microscope, the Streptococci appear as Gram-positive.

5.4 ASSESSMENT OF SURFACE SANITATION

Bacterial counts on utensils, equipment, working surfaces, walls, floors etc., are useful means of assessing the standard of hygiene and the efficiency of cleaning procedures in food factories. The **'Swab Rinse Method'** is useful for the purpose.

For the swab method, pre-sterilized cotton swabs are used. The sterile swabs are dipped in sterile Ringer solution and rubbed over the required surfaces. The rubbed swabs are allowed to stand in sterile Ringer solution for 20-30 min and shaken. This solution is used to make plate counts with yeast extract agar. The Ringer solution inoculated into MacConkey broth should not show positive test for coliform organisms for well-sanitised surfaces. For bins and large utensils, sterile Ringer solution is used to rinse them. The rinsed solution is plated and inoculated in MacConkey broth as above.

5.5 MICROBIOLOGICAL EXAMINATION OF FOOD SPOILAGE

Microbiological spoilage of foods and its examination is an extremely wide area. Therefore, in this section, microbiological examination of spoilage of canned vegetable products, which is the most important, is discussed.

Canned Products

Canned food spoilage has both monitory loss and public health implications. Microbiological spoilage of canned fruits and vegetables is due to either under processing or post processing contamination (leakage). Under processing is due to insufficient heat treatment resulting in failure to destroy all microorganisms capable of subsequent growth in the product. Leakage is due to contamination of the product, mostly during the cooling process due to faulty seam or damage to the can. Microbiological examination of the spoiled cans help in identifying the cause of spoilage and take remedial measures.

The nature microorganisms associated with spoilage of canned fruits and vegetables is related to the pH of the products. As you have learnt, the spoilage of acidic foods like most fruit products is less critical from safety point of view. The pH of most canned fruits ranges from 3.7 to 4.5. In such products, spoilage is usually caused by aerobic and anaerobic spore formers, though Lactobacilli and Leuconostocs are also encountered occasionally. Tomato is a critical product having pH in the borderline between acidic and low acid foods. Butyric anaerobes and aciduric flat sours are important spoilage organisms of tomato products.

Spoilage in low acid (pH more than 4.5) canned products like vegetables; vegetable soups etc., spoilage due to under processing are caused by thermophiles. Some of these organisms and the type of spoilage are given below.

Bacillus stearothermophilus	:	Causes flat sour spoilage
Cl. thermosaccharolyticum	:	Causes hard swell
Cl. nigrificans	:	Causes sulphur stinkers
Mesophilic spore formers	:	Cause putrefaction

Spoilage due to can leakage is characterised by the presence of a variety of organisms including non-thermophilic organisms like various cocci including Leuconostoc and micrococci. The presence of micrococci and/ or yeasts is almost certain evidence of can leakage.

Examination of can spoilage is an elaborate process. The first step is sampling. If the spoilage is widespread, about 6-12 cans from each batch may be sufficient. Other wise the number of cans required will be quite large. The sampled cans are subjected to the following examinations.

Physical examination: The following parameters are recorded.

i) Name of the product

ii) Code mark

iii) Can size (A1 tall, A2 ½, A10 etc.)

iv) Gross weight

v) Physical condition of the can like mechanical defects, pin holes, swell etc

vi) External seam dimensions

Incubation: The cans are incubated at different temperatures depending on the pH category as below before further examination. Incubation facilitates the multiplication of the surviving organisms, which helps in the subsequent examinations.

Fruit products (pH 4.5 and below): 37^{o} C for 3 days

Vegetable products: Some at 37^{o} C and the remaining at 55^{o} C for 3 days

The cans are examined periodically during incubation and if any cans are swollen, they are removed. After incubation, the cans are cooled before opening.

Opening the Can and Sampling

The cans have to be opened under sterile/ aseptic conditions using sterilizes implements and gas flame. Special type of punches and openers are available for the purpose. Sample is drawn out using sterile glass tubing into a sterile container.

Sample Examination

The sample is used for direct microscopic examination, culturing, pH determination etc. The can under examination is emptied and observed for it's inside appearance and the seam dimensions are examined.

pH determination is important when flat- sour is suspected. As a routine procedure, the net and drained weight of the can is determined and the product quality is visually examined. Test sample should never be tasted. Combustible nature of the gas (hydrogen) in swollen cans can be checked by puncturing the can and directing the gas to a flame. The can interior of hydrogen swelled cans will show heavy corrosion. In the case of sulphur stinker, the can interior will show black or purplish black stain.

Direct Microscopic Examination

The sample taken from the can is smeared on glass slides and stained with methylene blue or carbol fuchsin and examined under the microscope for general morphology of the organisms. Separate slides are also Gram-stained.

The presence of Gram-positive rods suggests under processing while cocci, yeasts etc., suggests leaker spoilage. If spoilage is due to bacteria surviving heat process, not more than one or two types would be present except in gross under processing. In the case of products having pH above 4.0, container leakage would usually show mixed flora. The presence of micrococci and/or yeast is a sure evidence of container leakage. Based on the information, preventive measures such as increasing the process time if under processed or rectification of the can seam if leakage is the cause are undertaken.

Culturing of the can contents is required to identify the microorganisms for further investigations on the spoilage. This is an elaborate process and is not carried out in routine quality control work.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which are the major parameters included in the microbiological examination of water?

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2. Explain the procedure for determining 'Plate count'.

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3. Describe the procedure for determining 'Coliform count'.

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4. Describe the 'Swab-rinse' method for assessing surface sanitation.

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5. Describe how a spoiled can is examined for spoilage.

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6. How does microscopic examination of the contents of spoiled can help in preventing subsequent spoilage?

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5.6 LET US SUM UP

As you have learnt, food quality assessment is based on physico-chemical, microbiological and sensory methods. Sensory methods for quality assessment are described under a separate unit.

Analytical food chemistry makes use of physico-chemical methods for determining the composition of foods. In food analysis, proximate analysis is routinely carried out to determine the proximate composition of foods. Proximate composition gives a general idea of the major components of foods. In ultimate analysis, individual compounds of the food are determined.

Many of the analytical methods commonly followed in food analysis are described in the Practical Manuals, which you will be performing. A few of those physico-chemical methods, which could not be covered in the practical Manuals, like determination of 'Crude fat', 'Protein', Pectin' and 'Tannins' are described in this unit.

Crude fat and protein are important parts of the proximate composition of foods. You have already learnt the nutritional importance of fats and proteins. Crude fat includes all fat-soluble constituents like tri-glycerides, phospholipids, sterols, essential oils, fat-soluble vitamins and pigments. Therefore, crude fat extracted from foods is used for determining those constituents also.

Microbiological quality of water used in food processing is very important from the food safety point of view. Potable water should conform to certain microbiological quality standards. The major parameters are plate count, coliform count and faecal Streptococci count. If water from a particular source is found unsafe, it should be treated suitably.

In the food processing industry, surface sanitation of the machinery, utensils etc. used should be thoroughly sanitized before use. The method followed to assess the efficiency of sanitation viz. Swab Rinse method is described in this unit.

Spoilage of foods cause monetary loss and may result in public health hazards. Canned low acid foods are of particular concern. Canned foods are generally spoiled either due to under processing or can leakage. The general procedure for examining microbiological spoilage in canned foods include, proper sampling of cans, physical observation of the cans, incubation at specified temperatures, opening the cans under sterile/ aseptic conditions, sampling the contents of the can (spoiled food material), microscopic examination and some times culturing the sample. Microbiological examination of spoiled cans helps in preventing their recurrence.

5.7 KEY WORDS

Proximate analysis : Nutritional and biochemical composition.

Ultimate analysis : Analysis of specific compounds and elements.

Crude fat : Lipids and fat-soluble components.

Tannins : Flavonoids and cinnamic acid derivatives.

Presumptive test : Tentative or unconfirmed test.

Flat sour spoilage : Spoilage in cans with acid formation without Bulging.

Hard swell : Can spoilage with hydrogen swell and heavy corrosion.

Under processing : Insufficient heat processing of cans.

5.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Nutritional and biochemical composition
   - Detailed analysis, analysis of individual compounds
2. Your answer should include the following points:
   - Tri-glycerides, phospholipids, essential oils, sterols, fat-soluble vitamins
   - Soxhlet apparatus
   - Ether extraction
3. Your answer should include the following points:
   - Acid digestion
   - Micro-Kjeldahl distillation method
   - % Protein = % Nitrogen $\times$ 6.25
4. Your answer should include the following points:
   - Acid extraction of pectin
   - Precipitation as calcium pectate
   - Gravimetric determination
5. Your answer should include the following points:
   - Antioxidant
   - Health benefits

- Oxidation of tannins by potassium permanganate

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - Total count
   - Coliform count
   - Faecal Enterococci count.
2. Your answer should include the following points:
   - Nutrient agar
   - Ringers solution
   - Plating
   - Incubation
   - Counting
3. Your answer should include the following points:
   - Presumptive test
   - Confirmed test
   - Completed test
4. Your answer should include the following points:
   - Cotton swab
   - Ringers solution for rinsing
   - Plating
   - Incubation
   - Counting
5. Your answer should include the following points:
   - Can sampling
   - Incubation
   - Can opening
   - Sterile conditions
   - Product sampling
   - Microscopic examination
6. Your answer should include the following points:
   - Spore formers
   - Gram-positive
   - Micrococci
   - Yeasts
   - Under processing
   - Leakage

5.9 SOME USEFUL BOOKS

1. Manual of Methods for the Examination of Water, Sewage and Industrial Wastes (1963) Special Report No. 47, Indian Council of medical Research, New Delhi.

2. National Cannerd Association (1968) Laboratory Manual for Food Canners and Processors, Vol. 1, The AVI Publishing Co., Conneticut, USA.

3. Official Methods of Analysis (1980) Association of Official Analytical Chemists, Washington, DC 20044.

4. Ranganna, S. (2000) Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw-Hill Publishing Co., Ltd., New Delhi.

5. Recommended Methods for the Microbiological Examination of Foods (1958) American Public Health Association Inc., New York.

UNIT 6 SENSORY ANALYSIS OF FOODS/ BEVERAGES

Structure

6.0 OBJECTIVES

After reading this unit, you should be able to:

- differentiate between sensory analysis carried out by a trained panel and casual testing by consumers; and
- explain the methods that should be used in the two situations as both are important in analysing food/ beverage.

6.1 INTRODUCTION

Food / beverage quality is composed of four major components. They are: (i) Intrinsic factors as nutrition, safety which are hidden, (ii) economic factors as investment and profit for a producer (iii) sensory quality noticed by the people as colour, appearance, taste, flavour etc. and (iv) affective quality which decides its ultimate acceptance and use due to like/dislike to a product. The producer is most interested in the last two components to see repeat purchase and good sale of his product. Definite methods to test the intrinsic quality and cost benefit analysis are available for the first two components. These involve human responses and are often confused as one and same. At the outset it should be understood that the two are different. The sensory component testing refers to stimulation of sense organs (Iyendria) and it purely refers to responses in analytical way. The consumer or affective test refers to response by a population, their like/dislike. It is a test for acceptance or rejection, preference or liking of a product (Indria) and not critical analysis.

The senses used in analysis of foods/ beverages by people are, the eye, which includes colour and appearance, the nose for the sense of smell/ aroma as felt by smelling or while swallowing the food, and by the tongue and interior of the mouth for the four basic tastes of sweet, sour, salt and bitter. The teeth while biting and feel on the tongue or by finger is another important sensory quality of food, as for example, softness of fruits, crispness of biscuit and papads etc. Figure 6.1 gives the idea of the sensations that foods create.

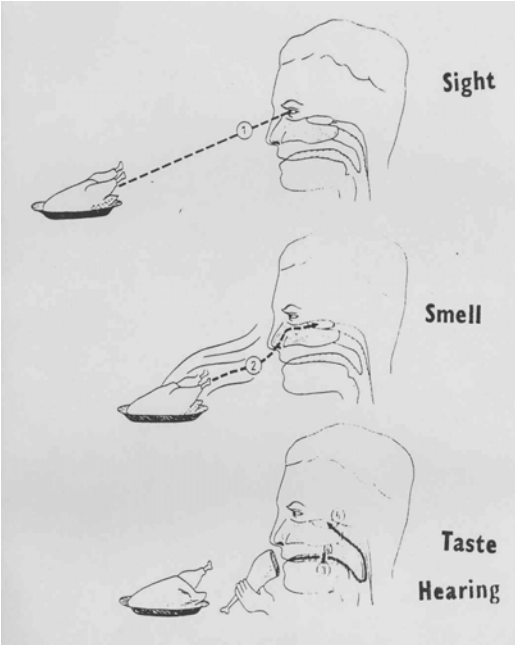

Figure 6.1: Sensory impressions by food

6.1.1 DEFINITION

Sensory analysis is a scientific discipline used to evoke, measure, analyse and interpret the reactions to food as perceived by sense of sight, taste, smell, touch and hearing. The sensory analyst will be equal to an analytical instrument, and will use his 'Iyendrias' (senses) as a tool. It is the 'Iyendria Moulya Maapan' only and not referring to personal likes and dislikes.

The ultimate use of food/beverage is achieved when people consume it. All human beings are endowed with sense organs and use them to judge colour, appearance taste, flavour and texture of food automatically. Is it not true we all look at the food we eat at home or outside for its sensory quality? Think and remember!!

However, this being a psychological response, it can be influenced by several factors. It is therefore important to test the product under careful conditions and in a scientific way.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are food qualities tested by people as tools called?

   a) Intrinsic quality test
   b) Economic quality test
   c) Sensory quality test
   d) Affective (consumer) qualities test

2. Give the definition of Sensory Analysis of foods.

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6.2 APPLICATION

Sensory analysis tests are used in foods/beverages, personal care products as cosmetics, perfumes, and also in textiles for examination of texture, smoothness, etc. Sensory tests are needed in production, research centres and in consumer studies as in market research or survey. We all have seen sensory quality discussed in basmati rice, instant coffee, shampoo, soap etc.

6.3 CONDUCTING SENSORY TESTS

We know sensory tests are carried out by a panel leader and can be either analytical test done by trained people or as affective test done by consumers. The following remain common to both.

6.3.1 Identification of Problem

The first factor to be considered by panel leader is to identify the problem to be looked into i.e., aim of the test should be known. Since sensory organs are simulated simultaneously, for example, aroma and taste, colour and appearance, etc. the objective of testing has to be clear and focussed. The judge has to look for these attributes only.

6.3.2 Selection of Method

Sensory analysis testing for food quality valuation has been in practice from a long time. It has been used for complex products as tea and coffee, whisky by special blenders and also for simple products as sweetness by flow calorie sweeteners. The choice of test method, however, is very specific to the objective of testing. International and national standards are now available to use uniform pattern of testing. This is given in detail under 4.6.

6.3.3 Panellists

Panel Selection

The panel of judges for laboratory sensory testing are usually selected from people with normal sensitivity and not super tasters. They are from office, co-workers in factory, research group and management staff. They are collected through circulars or personal contacts. People from both sexes are used. The eagerness to participate is the first requirement, as they have to be interested in it. Initial information on age, sex, health status, likes and dislikes, educational background, availability is necessary. In consumer tests, the target population should be selected. We have to see who uses the product and decides to buy it and they have to test it. For example chewing gum flavour is best tested by teenagers and quality of cooking oil by housewife.

Panel Training

In laboratory sensory analysis, the level of training required depends on the type of test used. It is first done to select a group of people who are sensitive to the required level. For example, ability to test off odour has to be done by carefully selected and trained people. Where more intricate analysis is required, more training with examples are used. The panel leader will select the degree of training needed. In consumer tests, no specific training is given to panellists and only method to fill up the answer sheets/ pro forma will have to be explained.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Sensory tests are done only for foods. Yes No
2. Aim of testing should be clear first. Yes No
3. Panel members should be super tasters. Yes No
4. Which of the tests need more training and why?

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6.4 FACTORS CAUSING BIAS IN SENSORY TESTS

In sensory tests since human subjects are used as tools, care must be taken to use bias-free conditions. Bias means bad influence. Several difficulties can come up which will disturb the analysis and affect the results. They can be due to physiological factors or psychological factors.

6.4.1 Errors Due to Physiological Factors

Errors due to physiological reasons could be the following:

i) *Health:* People with common cold cannot perceive smell and taste. Textural properties, particularly biting quality cannot be judged by people with artificial molar teeth.

ii) Age is another factor which will influence sensory perception. With proper training and motivation it is possible to use panellists of all ages but care must be taken to avoid too young and too old age group.

iii) Adaptation can occur in sensory in nose or tongue when a product is to be tested continuously. For example testing of pungent compounds or bitterness can make a panellist more tolerant of sensation in a product.

iv) Enhancement of sensation can occur in some situations, for example perception of sweetness can be increased with some other substances as sourness. This is commonly observed in testing gooseberries or bitterness in coffee with added chicory.

v) Suppression of taste sensation is the opposite effect of enhancement and commonly observed in foods. This effect will modify the taste sensation. This is observed in combination of pungent and salt tastes or even addition of oil or fat to a food.

6.4.2 Psychological Factors

In sensory testing, psychological factors play an important role. We all know each of us is capable of thinking and imagining. Some common psychological factors, which bias judgement, are as follows.

i) Anticipatory or expectation errors. This occurs due to the panellist starting to test with a pre-conceived idea. Information received earlier can influence judgement. For example, this may happen in testing sweet tasting low calorie foods.

ii) Stimulus error can occur due to other sensory impression in the same product, for example intense colour in fruit juice is considered strong in flavour. Even irrelevant issues can cause bias in judgement as packaging of product can give a bad influence.

iii) Logical error can come up due to the imagination of panellist. For example, cakes with lot of holes may be expected to be soft and spongy or chapathi with brown spots will be considered soft and well cooked.

iv) Halo effect is another situation of bias where the testing is to be done on 3 to 4 attributes and confuse the panellist if he/she is not careful.

In addition to these factors, testing sequence can also cause bias, as for example first sample tested will be seen critically. Over eagerness to perform well in tests or cross talk can influence the test. The panel leader should minimize these factors, which can bias judgement. The panellists should remain calm and interested to concentrate on the test.

In consumer tests, testing place as in a school or shopping area or home may be a bad influence if wrongly selected.

6.5 PHYSICAL SET UP FOR CONDUCTING SENSORY TEST

6.5.1 Laboratory Set Up

Three main areas are required for sensory testing of foods. They should be away from busy corridors and separated by wall or wooden partition. They are: (i) briefing room, where the panellist is told all about the product to be tested, testing method and number of samples (ii) testing room with table to keep the samples and write the score card. Lighting and ventilation should be good. Each panellist should be separately seated and not in the visual reach of each other (iii) the third area should have sufficient place to keep all plates and cups used in test. All samples should be presented in uniform containers and coded numbers. Figure 6.2 gives a picture of a testing room in a laboratory set up.

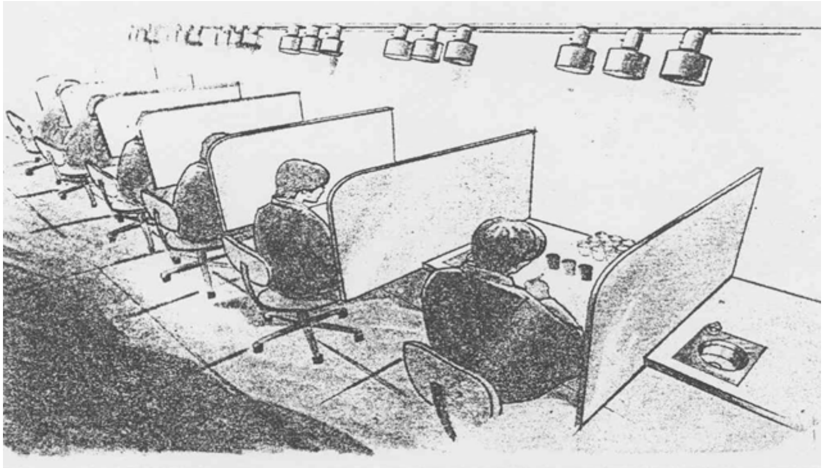

Figure 6.2: Laboratory setup for sensory testing

6.5.2 Consumer Testing

The physical set up depends on product and target group of consumers. It can be a central location testing in shopping area, college campus, hospital, etc.; it can be in club house or homes of friends. Essential requirement in all is to have similar cups and plates with code numbers for all products tested.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Bias in sensory test (wrong influence can arise due to a) Physiological, b) Psychological factors.

Yes No

Give two examples for both.

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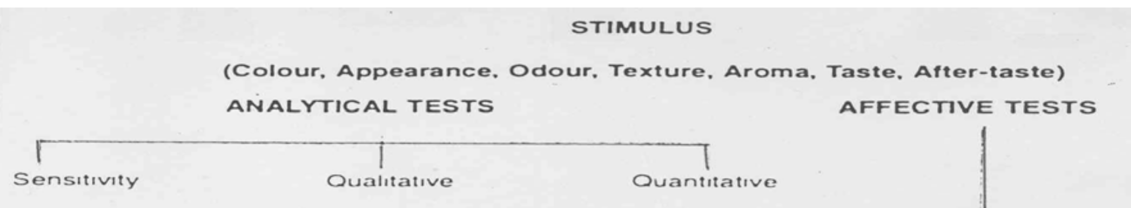
6.6 SENSORY TEST METHODS

Bureau of Indian Standards follows the internationally standardised sensory test methods also. The Table 6.1 gives the test methods adopted. The first distinction is between analytical methods i.e., laboratory test method and second is the affective or consumer test method.

Table 6.1: Sensory testing methods



6.6.1 Analytical Tests

These are the laboratory methods used to test the product for its sensory quality.

Sensitivity Test

This refers to basic difference test. It can be performed as threshold test to identify a sensory impact. Threshold tests are used, for example, to select people with normal sensitivity to sweetness or saltiness. It can be used to detect adulteration Samples are tested in a line till they find out the sensation.

Sensitivity tests can also be done as discriminative test in pairs or triangle. These two-sample tests are simple. We all know it is possible to compare one with just another easily with out confusion. The order of examining, which is first? which is second? should be properly planned to avoid the bias that first is always best. For example think of comparing a new orange drink with fresh juice. Paired test is by testing two samples at same time and see if they are same or different. Figure 6.3 shows how the samples are arranged. You will see 4 pairs of sample arranged for testing. Plain water is used in between samples. Only small quantity of test sample is given under coded numbers.

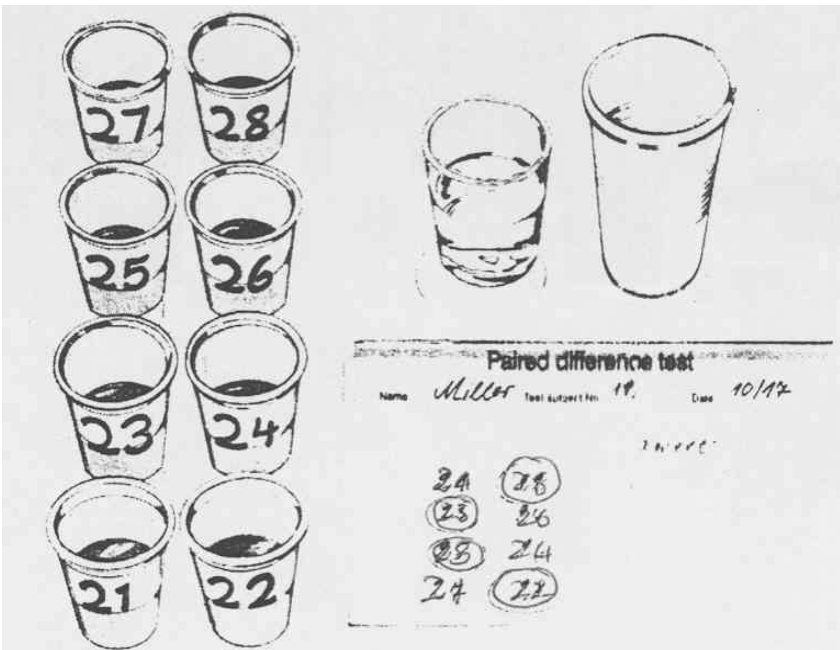


Figure 6.3: Paired comparison test

Minimum 7-10 panellists should examine the samples. Test results are checked for significance of difference by referring to statistical tables.

Triangle test is another method for difference test. The samples are presented in groups of three. Here two are identical and one is odd. The test is to identify the odd sample. For analysing the data, the total number of correct identification is counted and referred to table for significance of difference.

Qualitative Tests

Many times more than two samples will have to be tested for more attributes. For this qualitative tests can be used. This test is useful for working with semi-trained panel of 7-10 members. One of the methods is to arrange the tested foods in the order of increasing intensity (e.g. strong or week aroma), or quality (e.g. good or bad aroma). Ranking is another method. For examples in chocolates, four to five brands can be tested for colour and appearance, texture, flavour and overall quality in one session. The panellist will have to arrange the samples in order of 1st rank for best colour then for best texture etc. Each attribute is tested separately. Classification method is another method. These can be for a specific category of sensory attributes for example as depth of yellowness in pineapple juice. The data in these tests is analysed using non-parametric method. The samples should be tested as coded samples and in random order to prevent bias.

Quantitative Test

In sensory tests to get information on 'how' and 'why' the foods are different, marks for the sensation felt has to be given. The panellists have to be trained more to do these tests and a minimum of 7 panellists are required. They have to be trained both to identify the sensation and give marks to it. This method is very useful for factory and research people. The methods are scoring, rating and time-intensity tests.

In scoring test, numbers as in figures or descriptive scores are used. These scores are useful when the panellists are well trained. For example in a product as jam, ketchup etc. scoring and grading for colour, consistency, set and aroma is useful. Similarly duration of sensory feeling can be matched with time-intensity as in natural and artificial sweeteners. The data is analysed for arithmetic mean and standard error. These quantitative tests can be tested further by detailed statistical tests. Indian standards institution has given details of these tests.

Quantitative description method, popularly called as QDA is another very useful methods for testing foods and beverages. It is a complete and detailed system of panel training, selection of range of products and vocabulary development in simple language. 8-10 well trained panellists can participate. For example description of Dosa or Samosa can be completely obtained and tested by this method. A reference can be maintained as a standard and any number can be tested by a panel. The method can be used to get difference, defects and desirable sensory quality. Recently available computer aided data analysis is very useful for testing.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Which are the two groups in sensitivity tests?

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2. For two samples ……………….. and …………………. tests can be used.

3. Qualitative test can be done with > 2 samples.

   Yes No

4. Significance of difference is decided by referring to statistical tables.

   Yes No

5. Which tests are used to know 'How' and 'Why' foods are different? What are the methods used to give marks?

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6.6.2 Affective Test

This group of tests is used to get the reaction of the consumer for the food. It tests the users opinion of the product. Three common methods are acceptance, preference and degree of liking. These tests need careful planning and the objective of the test should be known. Question should be asked accordingly. Selection of people who do the tests should be correct, for example baby foods should be tested by mothers and traditional family food should be tested by all at home. Consumer attitude will also change and it is better to check the target population periodically. The number of samples in consumer tests should not be more than two. Consumer response study should never be less than 50 number and 100 will be best. The questionnaire should be as simple and focussed as possible and related to the objective. Consumer tests can be handled for the four types of problems given below:

Acceptance Test

Acceptance is the simplest decision making job for the consumers but only one sample should be tested in one session. They should be asked to concentrate on attribute like for example, overall quality or aroma of new variety of rice, etc Since consumers will relate it to other factors as price, it can be done only at a central location in a shopping complex, college campus, etc., A new product can be tested here. These tests can be done at home also for example, a new masala mix for rice. Results are given as percentage of people accepting it.

Preference Test

Preference test is another possibility in consumer tests. Not more than three samples should be tested at a time. This can be as 1st, 2nd, and 3rd preference. It should be done by consumers who are familiar with the product. For example cola a type of drink, by college students and instant coffee by office staff.

Hedonic Test

Hedonic test is a direct reference to personal like/dislike to a product. The test is done on 5 or 7 point scale of 'like very much' to 'dislike very much'. The actual users will have to test the food/beverage. New product for example, noodles, shakthi drink etc., can all be tested by this method. Here also a minimum of 100 responses will have to be collected. Figure 6.4 shows one sample of score card for children's food. Here results are as percentage liking it or not.

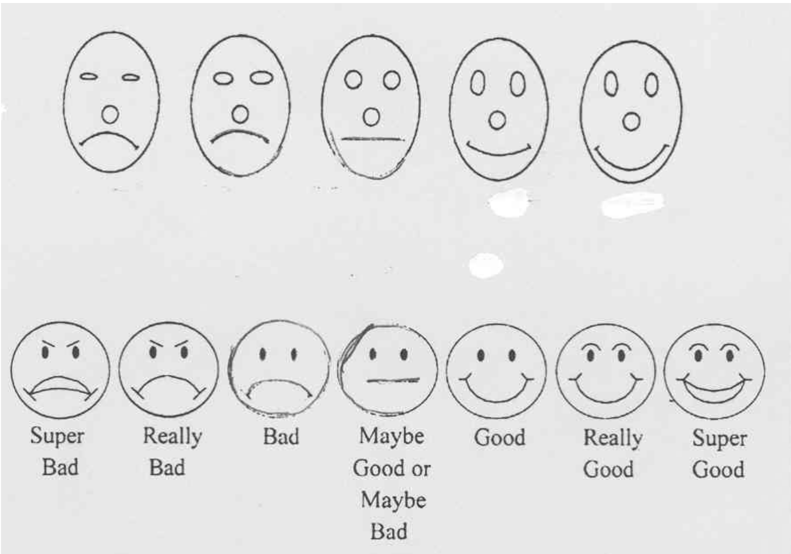

Figure 6.4: consumer evaluation card

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How many people should do the consumer tests?

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2. In consumer tests three types are used, they are a) acceptance, b) preference, c) like. What is the opposite of these three?

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6.7 SENSORY TEST AND INSTRUMENTAL MEASURES

The sensory test when carried out by scientific method will be useful to support instrumental tests. The following are some corresponding tests.

6.7.1 Visual Examination

Visual examination is by the rods and cones in the eye where colour, shape, structure, freshness, etc. are observed. The human eye can distinguish up to 1500 different hues/shades of colour. For example, degree of colour in fruits from green to over ripe fruits, the shades of brownness in chocolates, etc. The instrumental measures for matching what the eye can see are in the visual range of 380–780 nm as L*a*b* tristimulus values in CIE system. The average level of difference as seen by people can be used to describe the colour. Shapes of foods are easier to be measured in terms of geometry of height, length, etc. This can be shown as example in cakes that are baked, sweetmeats as jelabi, etc. Degree of freshness can be noticed in some products by checking for bubbliness, in some beverages as soda and orange.

6.7.2 Texture Examination

Auditory (hearing) sensation in foods is caused by stimulation of ear drum by the sound waves. This is called as texture as crispness of papads or fresh fruits as in apple, etc. It is what the teeth feel when biting the food. It is closely related to structure and movement of food in the mouth. There are advanced texture measuring instruments to study the hardness, softness of food and viscosity of beverages.

6.7.3 Olfactory – Sense of Smell

Olfactory or sense of smell is a chemical stimulation of the receptors in the nose and upper oral cavity. Human odour memory is short but can be trained to recall. Up to 150 odour types can be differentiated. The air carries the chemicals that give the smell. It is difficult to understand how nose can pickup differences in mango variety or bad smell due to toxins. Instrumental measures as gas chromatography or headspace volatiles are used to analyse the individual chemicals. Recently electronic nose is developed to match human response.

6.7.4 Gustatory – Sense of Taste

The sense of taste noticed by tongue and parts of oral cavity are developed early in human beings. Preference for sweet taste is seen even in one week old babies. Instruments for measuring salt content, sweetness and sourness are available. The simple ones are Brix (sugar content), sodium chloride content and pH (food acid content). Special methods are also there.

6.7.5 Flavour

Flavour is the common term for the total effect of odour, taste and touch experienced by people. It is a sensation more closely related to aroma when the food/beverage is put in the mouth. Highly trained panel only can test this. No single instrument can measure this sense.

Check Your Progress Exercise 6

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Sensory tests for colour, shape and texture can be related to instruments.

   Yes No

2. What causes smell in the nose and how do they reach the nose?

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3. No single instrument can measure total flavour test.

   Yes No

6.8 LET US SUM UP

In this unit we learnt that sensory analysis of foods and beverages refers to using humans as instruments/tools. The analytical tests for colour shape, aroma/odour, taste and texture of foods are done by trained people called panellists. Like/dislike, acceptance/rejection are tested by normal consumers is affective tests and done by consumers. Tests have to be carried out under bias free conditions i.e., without wrong influence. Specific methods of testing and analysing data is given by Indian Standards. There are three major types of analytical tests. We need not use any super taster but people like you and me can do the test. There are three types of consumer tests. For analytical tests seven to ten members are needed and for consumer test at least 50 people should be used. For all sensory tests, some instrumental analysis is possible but not for total flavour and acceptance or liking. Only human beings can tell this.

6.9 KEY WORDS

Senses of humans	:	Eye for Colour and shape, teeth and flow in the mouth for texture and viscosity, nose and back of throat for smell and aroma of food. Tongue for taste.
Analytical sensory Tests	:	Tests done by trained people.
Consumer tests	:	Tests done casually in markets, schools etc.
Sensitivity tests	:	Threshold and two sample tests.
Qualitative test	:	More than two samples for arranging in order.
Quantitative test	:	Tests where marks are given.

Iyendria	:	Senses (analytical).
Indria	:	Likes/ dislikes (affective).
Sensory analysis	:	Iyendria Moulya Maapan.
Bias	:	Bad influence.

6.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. b) Sensory quality test
   d) Affective quality test

2. Sensory analysis is a scientific discipline used to evoke, measure, analyse and interpret the reactions to food as perceived by sense of sight, taste, smell, touch and hearing. The sensory analyst will be equal to an analytical instrument.

Check Your Progress Exercise 2

1. No
2. Yes
3. No
4. Analytical tests need more training of panellists as the judge has to perform like an instrument.

Check Your Progress Exercise 3

1. Yes

   Examples: Physiological bias- Fever, adaptation
   Psychological bias- Expectation error, cross talk

2. a) Wrong
   b) Wrong
   c) Right
   d) Right

Check Your Progress Exercise 4

1. a) Threshold test
   b) Discrimination test
2. *Paired* and *Triangle* tests
3. Yes
4. Yes
5. Quantitative tests are used to get answers on how and why foods are different. The methods to get marks are, scoring, rating, scaling and time-intensity tests.

Check Your Progress Exercise 5

1. At least 50 people should do the tests.

2. a) Rejection
   b) No preference
   c) Dislike

Check Your Progress Exercise 6

1. Yes

2. Chemicals reaching the nose cause the sensation of smell. They are carried by the air we breathe in.

3. Yes

6.11 SOME USEFUL BOOKS

1. Indian Standards (1968) IS 6273 parts I-III.

2. Shanthi Narasimhan and D. Rajalakshmi (1999), Sensory evaluation of fermented foods, in Biotechnology: Food Fermentation, Vol. 1, Ed. V.K. Joshi and Ashok Pandey: Educational Publishers and distributors, Asia Teca Publishers Inc. New Delhi, p.346-382.

UNIT 7 ANALYTICAL INSTRUMENTATION – ANALYTICAL BALANCE, pH METER & CHROMATOGRAPHY

Structure

7.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the principle of measurement of mass;
- describe the different types of analytical balances;
- explain the principle of pH measurement;
- explain the principles of chromatographic techniques; and
- describe the instrument details if gas chromatograph.

7.1 INTRODUCTION

In Unit 3.2.1, you have learnt some of the analytical and quality control methods based on the physical properties of food components. You have also learnt that instrumental methods are becoming the preferred methods over the classical volumetric and gravimetric methods. Some of the instruments are becoming more and more sophisticated and capable of automatic analysis. Even the simple analytical balance used for all analytical determinations has gone through a lot of developments and has become highly complex and refined. Therefore, all those engaged in analysis and quality control of food and food products should have some basic knowledge of the instruments, which they will be using.

In the following two units, you will be learning about a few important instruments. Microscope, a very important instrument, will be dealt with in another unit along with microbiological techniques. Some methods like texture measurement and reflectance colour measurement require more theoretical explanation to understand. Therefore, they are covered under physical methods in Unit 3.2.1. It is presumed that gadgets and equipments like gauges, hydrometers, ovens etc. are so simple that they can be straight away handled.

In this unit, you will be learning about modern analytical balances, pH meter and chromatography.

7.2 MEASUREMENT OF MASS

In the course of most chemical/ food analysis, an accurate and reliable measurement of the mass (weight) of a sample is required. The terms **'mass'** and **'weight'** are often used synonymously but they are different. Mass is a fundamental quantity which is an invariant measure of the amount of matter in an object. Weight is the force of attraction that exists between an object and its surroundings, mainly the earth. Therefore, the weight of an object varies with the altitude of the place where it is weighed. For example the weight of a coin is less in Shimla than in Mumbai whereas the mass of the coin remains constant in both the places. Weight and mass are related by the expression:

$$W = M\,g$$

Where, **W** is the weight of the object, **M** is its mass and **g** is the acceleration due to gravity. In order to free the results from dependence upon altitude, a **balance** compares the weight of an object with the weight of a set of standard mass. Because g affects both unknown and known masses equally, an equality between their weights indicate an equality in mass. Therefore, measurement of mass is usually referred to as weighing and the results of weighing are called weight.

7.2.1 Analytical Balances

An analytical balance is a weighing instrument, which has a maximum capacity ranging from 1g. to a few kilograms but usually 160 to 200 g. Weighing can be made with a precision of ± 0.1 mg. Semi micro analytical balances have a maximum loading of 10 to 30 g. with a precision of ± 0.01 mg. and micro analytical balances have a capacity of 1 to 3g and precision of 0.001 mg. The analytical balance has undergone significant evolution during the past several decades. The traditional analytical balance had two pans suspended from the two ends of a lightweight beam, which was supported on a knife-edge. Single pan balance is more convenient to use and hence has almost completely replaced the double pan balance.

7.2.2 Mechanical Single Pan Balance

The two types of balances, however, have several common fundamental features. The components of a mechanical single-pan balance is shown below (Figure 7.1):

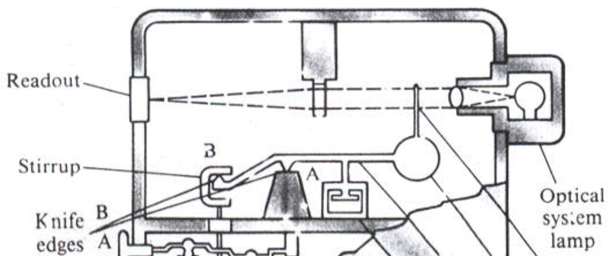

Figure 7.1: Single-pan analytical balance

A lightweight beam is supported on a hard surface (agate or synthetic sapphire) by a knife-edge A. At the left end of the beam there is one more knife-edge B from which a pan for holding the object to be weighed and a full set of weights held in place by hangers is attached. These weights can be lifted from the beam, one at a time, by a mechanical arrangement that is controlled by a set of knobs on the exterior of the balance case. At the right end of the beam a counter weight is fixed which just balances the pan and the weights on the left end of the beam.

The performance of a mechanical balance is critically dependent upon the perfection of the knife-edges. They should permit motion of the beam and pan with minimum friction. To protect the knife-edges from damage and ware when an object is placed on the pan or when the balance is not being used, the balance is equipped with a beam arrest and a pan arrest.

An air damper is mounted near the end of the beam opposite the pan. This device consists of a piston that moves within a concentric cylinder. As the beam is set in motion, air in the cylinder undergoes expansion and contraction causing opposition to the motion bringing the beam rapidly to rest. When there is no object in the pan, the beam will be in horizontal position. When an object is placed in the pan, the beam is displaced downward. Weights are then removed one by one from the beam until the imbalance is less than 100 mg. The angle of deflection of the beam with respect to the horizontal position is directly proportional to the mg. of additional weight that must be removed to restore the beam to its original position. The optical system measures this deflection and converts the angle to milligrams. A small transparent screen mounted on the beam has 1-100 mg. markings. A beam of light passes through the scale to an enlarging lens which in turn focuses a small part of the enlarged scale on to a frontal glass plate located on the front of the balance. A vernier makes it possible to read this scale nearest to 0.1 mg. Before the weighing starts, the vernier is adjusted so that the scale reading is zero.

7.2.3 Electronic Analytical Balance

The electronic balance has neither a beam nor knife-edges. The diagram of an electronic analytical balance is shown below (Figure 7.2):

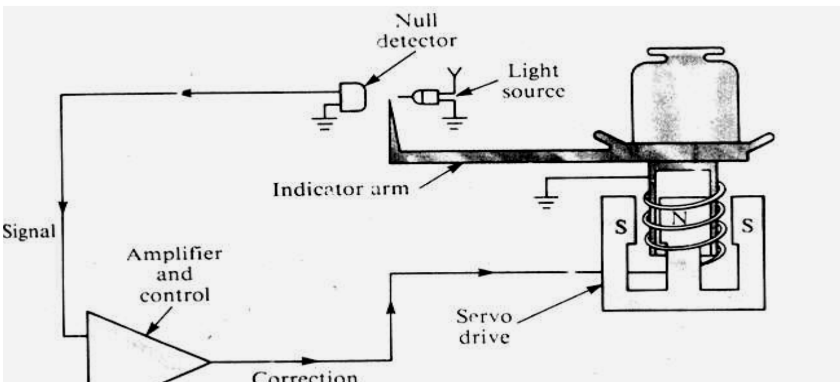

Figure 7.2: Electronic analytical balance

The pan of the balance on which the object to be weighed is placed rides above a hollow metal cylinder which is surrounded by a coil and fits over the inner hole of a cylindrical permanent magnet. An electric current in the coil creates a magnetic field, which levitates the cylinder, the pan and indicator arm. The current is so adjusted that the level of the indicator arm is in null position when the pan is empty. When an object is placed in the pan, the pan along with the indicator arm move downward, which increases the amount of light striking the photocell of the null detector. The increased current from the photocell is amplified and fed into the coil, creating a larger magnetic field, which returns the pan to its original null position. A device like this, in which a small electric current causes a mechanical system to a null position, is called a servo system. The current required to keep the pan and the object in the null position is directly proportionate to the weight of the object and is readily measured, digitised and displayed. Electronic balance is calibrated with a standard mass.

7.3 pH MEASUREMENT – pH METER

You have learnt about the importance of pH in food analysis, food preservation as well as its role in the sensory quality (flavour and taste of foods). You also know that precise maintenances of pH of biological systems is essential for their survival. Therefore, an accurate measurement of pH is of great importance. Before you learn the instruments for measurement of pH it is important to have a clear understanding of pH itself.

Pure water undergoes self-ionisation as follows:

$$2H_2O = [H_3O^+] + [H^-]$$

$$H_3O^+ \text{ is essentially } H^+ + H_2O$$

Since the extent of ionisation is negligible and hence the concentrations of $[H_3O^+]$ and $[OH^-]$ are also negligible, the ionisation constant

$$Kw = [H_3O] + [OH^-]$$

Taking the negative logarithms of both sides

$$PKw = pH + pOH$$

Kw has a value of 1.0×10^{-14} at 24°C (it increases slightly with increase in temperature, e.g. At 100°C the value is 49×10^{-14})

Since $\quad [H_3O^+] = [OH^-]$

$$Kw = [H_3O^+]^2$$

Or $\quad [H_3O^+] = \sqrt{}\ 10^{-14} = 1 \times 10^{-7}$

Therefore, $\quad pH = -\log(1.00 \times 10^{-7}) = 7.00$

At 24°C, any solution whose hydronium ion concentration exceeds 1.00 × 10^{-7}M i.e. 1.0 × 10^{-6}, 1 × 10^{-5} is acidic and any solution whose hydronium ion concentration is less than 1.00 × 10^{-7} M i.e. 1 × 10^{-8}, 1 × 10^{-9} is basic.

pH Meter

pH meters are based on the principle of potentiometry. Potentiometry is the measurement of potentials or voltages of electro chemical cells. An electrochemical cell has two electrodes namely a reference electrode and an indicator electrode or working electrode. An electrode potential of a reference electrode is known and is independent on the composition of the solution under study. The potential of the working electrode employed in conjunction with the reference electrode on the other hand is dependant on the concentration of the solute under investigation. The third component of an equipment required for potentiometric measurement (including pH measurement) is a potential measuring device.

There are three important reference electrodes. They are (1) Standard Hydrogen Electrode (SHE), (2) Saturated Calomel Electrode (SCE) and (3) Silver – Silver chloride Electrode. Even though SHE is the ultimate reference against which the potentials of all other electrodes are measured, it is not convenient to use for routine purposes. Therefore, the later two are often used. The indicator or working electrode for pH measurement is the glass membrane electrode.

7.3.1 Glass Electrode

Glass electrode is a type of ion-selective electrode (ISE). ISEs permit selective determination of numerous cations and anions. The basic principle of glass electrode for the measurement of hydrogen ion concentration is the measurement of the potential that develops across a special type of thin glass membrane that separates two solutions having different hydrogen ion concentrations. Figure 7.3 shows a typical glass electrode.

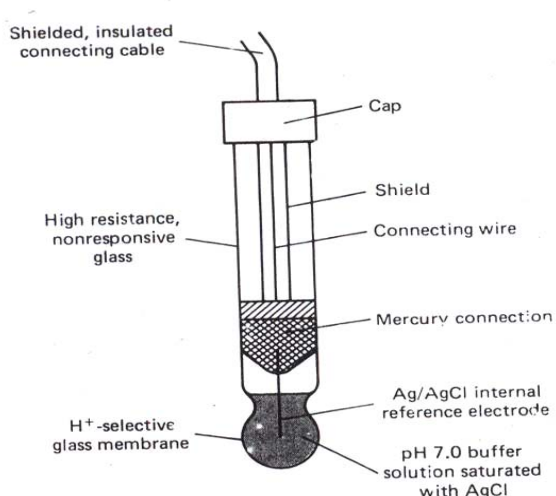

Figure 7.3: Glass electrode

The glass electrode consists of a thin, pH sensitive glass membrane sealed onto one end of heavy-walled non-responsive glass or plastic tube. The internal element consists of silver-silver chloride electrode immersed in a pH 7 buffer saturated with silver chloride. Some glass electrodes contain dilute hydrochloric acid saturated with silver chloride. A silver wire in this solution forms a silver/silver chloride internal reference electrode. The complete system consists of a glass electrode with an internal reference electrode, calomel or silver/silver chloride reference electrode and a potential measuring device. Although, the internal reference electrode is part of the glass electrode, it is not the pH sensing element. Instead it is the thin glass membrane at the tip of the electrode that responds to the pH.

Glass electrodes are available in a variety of sizes and shapes. For example, semi microelectrodes are so small that they can be used to measure the pH of solutions as little as 0.2 ml. There are also electrodes in which the glass electrode and a reference electrode like silver/silver chloride electrodes are physically combined and encased in a single tube. These **combination electrodes** have the advantage of being more compact than a separate two-electrode system. Figure 7.4 shows a diagram of a combination glass pH and silver/silver chloride reference electrode.

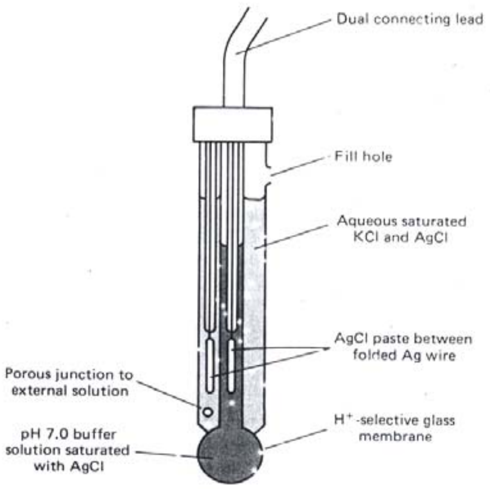

Figure 7.4: Combination pH electrode

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is the difference between mass and weight?

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2. Describe the essential components of a mechanical single pan analytical balance.

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3. How does an electronic balance differ from a mechanical balance?

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4. Why the pH of pure water is 7.0?

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5. Describe the main components of a pH meter.

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7.4 CHROMATOGRAPHY

Chromatography is a method of separation of the components of a mixture of closely related compounds and depends upon the distribution of these components between two immiscible solvents. The separated components are detected usually as such or after converting them to coloured complexes. Other signals such as thermal conductivity, visible, ultraviolet and infrared absorption, refractive index and electrical conductance have also been employed to complete the analysis. There are a number of chromatographic separation techniques, which you will be learning in this section.

Tswett is credited with the major part of the discovery and description of chromatography. Since the initial studies were on the separation of coloured components, the method came to be known as chromatography, which means **'description of colours'** or **'writing in colours'.** However you will be learning that present day chromatographic methods are not restricted to separating coloured substances.

Even though the basis of chromatography was laid in the beginning of the 20th century, it was only in 1941extensive work on chromatography was carried out and it's vast potential was realised. This was mainly sue to the work of Martin and Synge who got the Nobel prize in 1952 for their contribution in the field. They did the developmental work on liquid/liquid partition chromatography using inert adsorbents in columns and also paper (inert cellulose) chromatography. Another development in chromatographic technique, which took place during the middle and later 1950s, is the thin layer chromatography (TLC). Stahl is credited for most of the early developmental work on TLC. Martin and Synge even suggested that there is no reason why the moving phase in chromatography should not be a gas. They used a moving gaseous phase to separate a mixture of fatty acids on a conventional liquid chromatography column. Thus gas chromatographic technique was born which has developed into a very powerful analytical tool today. However, it has to be accepted that the modern gas chromatography owes a lot to the development of high sensitivity detection systems.

7.4.1 Classification of Chromatographic Methods

In any chromatographic method, the components to be separated are distributed between two phases. One of the phases is the stationary phase and the other flows through or along the stationary phase and is called the mobile phase. The mobile phase carries along with it the mixture of compounds to be separated. The mobile phase can be either liquid or gas while the stationary phase can be a solid or liquid. **Adsorption chromatography** is in which the stationary phase is a solid and the mobile phase is a liquid. Most of the column chromatographic methods are based on adsorption. The separation process in which both the stationary and the mobile phase are liquid is called **partition chromatography.** Even column chromatography and paper chromatography in which a liquid stationary phase (mostly water) is held on the inert solid support (column filling material or paper) are basically partition chromatography. However it has to be noted that the overall separation process in liquid/ liquid chromatography is most likely due to a combined effect of adsorption and partition.

When the mobile phase is a gas, two possibilities similar to the above are possible. One is in which the stationary phase is a solid and is called **gas – solid chromatography**. The second, which is more popular, is called **gas – liquid chromatography (GLC)** in which the stationary phase is a liquid held on an inert material. Due to the wider application of GLC, quite often it is referred to as just gas chromatography (GC).

Thin layer chromatography (TLC) can also be based on liquid/ liquid or solid/ liquid principle. Somewhat unrelated separation processes viz. ion exchange chromatography and exclusion chromatography are also often included under chromatography. A schematic representation of different chromatographic methods is shown in the Figure 7.5.

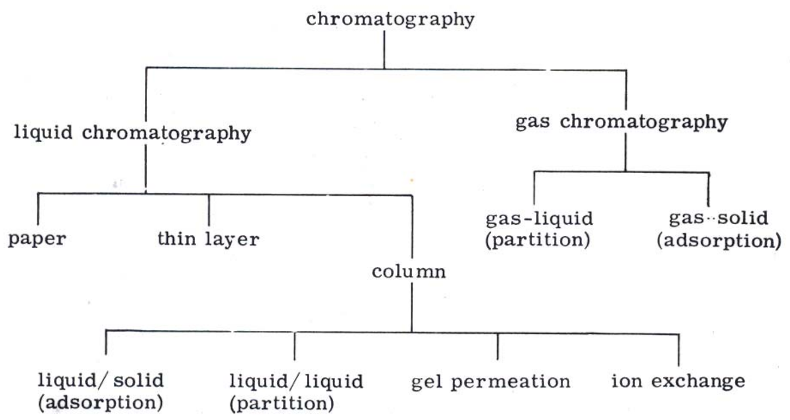

Figure 7.5: Classification of chromatographic methods

7.4.2 General Principles of Chromatography

A sample of a mixture of solutes applied to the stationary phase of a chromatographic system (column, paper or TLC) is carried by the mobile phase (liquid or gas) through the stationary phase. Depending on the nature of the mobile phase, the transfer of components from the stationary phase to the mobile phase is due to one or more of the following factors.

i) adsorption on to the stationary phase,

ii) partition into the liquid stationary phase,

iii) formation of polar bonds with ionic components of the stationary phase.

Separation of the components of a mixture by chromatography is based on the principle that the speed of movement of an individual component through the stationary phase depends on its partition between the two phases. The partition coefficient of each component depends on its sorption characteristics under the experimental conditions. If the sorption characteristics of the individual components of a mixture differ significantly, they move through the chromatographic system at different rates resulting in their separation.

The chromatographic behaviour of a solute is described generally by its retention factor (R). In chromatographic work, the retention factor is termed as Rf value.

$$Rf = \frac{\text{Distance moved by the solute}}{\text{Distance moved by the mobile phase}}$$

Rf value of a substance is more or less constant for a fixed set of chromatographic conditions and hence is used as one of the criterion for its identity.

7.4.3 Paper Chromatography

As mentioned already, paper chromatography is essentially liquid/ liquid partition chromatography. The stationary phase is the water, which is held by the inert cellulose of the filter paper. The mobile phase is a solvent, usually a mixture of solvents saturated with water. Obviously, such a system is suitable for separating hydrophilic compounds and not hydrophobic compounds. For separating hydrophobic compounds, modified filter papers are required. The paper used for paper chromatography is usually Whatman No.1 or No.2. Thicker filter papers are used for separating larger quantities of a mixture for extraction (elusion) and further studies.

General procedure: After selecting a suitable filter sheet of desired dimension, a pencil line is drawn parallel to one edge of the filter paper. Only pencil should be used for drawing the line or for making any markings because ink may dissolve in the solvent. The distance of the pencil line from the edge of the paper depends on whether one is carrying out descending or ascending chromatography. The difference between the two will be explained subsequently. For descending chromatography the line should be about 10 cm. from the edge of the paper and for ascending chromatography about 2 cm. is sufficient. In descending chromatography the pencil line should be drawn in such a way that while placing the paper in the tank assembly it should be after the antisyphon rod.

Application of sample: Sample preparation for different groups of compounds varies considerably. They are quite elaborate and are described in their respective methods available in textbooks or publications. Therefore, they are not included in this section.

Due to the simplicity of the technique, separation of a large number of substances has been achieved by paper chromatography. However, it should be kept in mind that paper chromatography is mostly used as a qualitative method, though in certain cases quantification is possible.

The samples are prepared in such a way that by applying a few **μl** of the sample is sufficient to detect the individual compounds on the chromatogram. The sample of the mixture is usually applied as a spot on the pencil line on the paper and allowed to dry by itself or by using a stream of hot air. Spots of solutions of known standard compounds likely to be present in the sample mixture are also made on the pencil line, each separated by sufficient space.

Development of the chromatogram: As mentioned earlier, there are two types of paper chromatographic techniques. Descending chromatography is one in which the mobile phase is allowed to flow down the paper by gravity. In ascending chromatography the solvent is allowed to rise on the paper. The requirements for ascending paper chromatography are rather simple. After applying the sample on the filter paper it is folded into a cylindrical form. The cylinder is fastened with thread along the sides to retain the shape. Subsequently it is placed in a petri dish containing an appropriate solvent (solvent mixtures for different groups of compounds have been developed) kept on a glass sheet and covered with a bell jar. Care should be taken to see that the solvent level is below the pencil line. The assembly is made airtight by applying grease. The solvent may take several hours to ascend to sufficient height (about ¾ of the paper). Care should be taken not to allow the solvent to reach the upper end of the paper. Subsequently, the paper is removed, and hung on a suitable support to dry. The separated spots are detected using suitable reagents if not coloured.

The assembly required for descending chromatography is more sophisticated. The tank assembly has a trough or boat on the top to hold the solvent into which the sample spotted edge of the filter paper dips. An anchor rod to hold the paper and an antisiphon rod to prevent siphoning of the solvent down the paper. A simple tank assembly is shown in the following Figure 7.6.

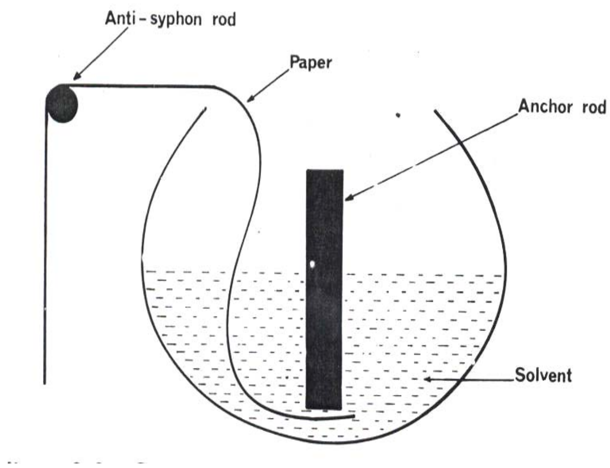

Figure 7.6: Cross section of descending chromatography trough

The rest of the sequence of operations are similar to those explained for ascending chromatography.

Some of the food constituents effectively separated by paper chromatography are: Carbohydrates, amino acids, organic acids, plant pigments, synthetic colours, vitamins, etc.

7.4.4 Thin Layer Chromatography

Thin Layer Chromatography (TLC) is similar to paper chromatography in several ways. The main difference is the nature of the chromatographic sheet. Instead of a filter paper it is a rectangular glass or plastic sheet. On the sheet, a thin layer (usually less than 1 mm.) of an inert material (coating material) like silica gel or alumina is applied. For imparting binding properties, substances like gypsum, polyvinyl alcohol is added to the coating material. For separating different groups of substances, different types of coating materials are used.

For forming a uniform layer of the coating material on the sheet, usually an **applicator** is used. The applicator has adjustment to control the thickness of the layer. The coating material is taken in the applicator as slurry and drawn over a set of sheets to form the layer. A schematic diagram of a TLC applicator is shown in the following Figure 7.7.

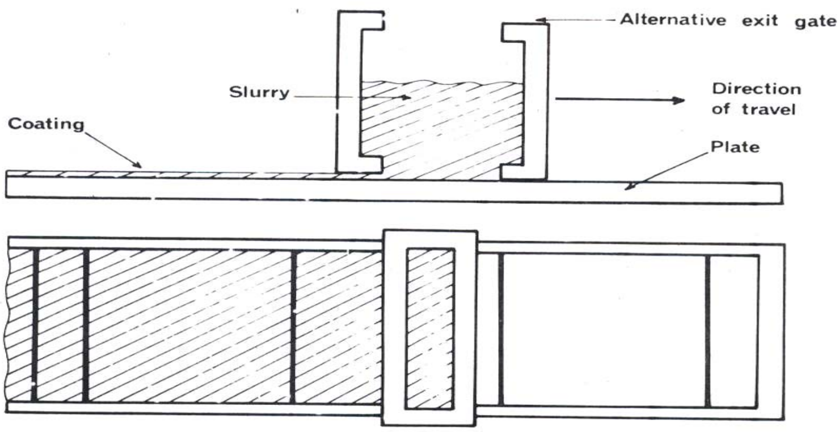

Figure 7.7: TLC applicator

After applying the slurry on the plate, it is allowed to dry in air. For adsorption TLC, the plates are subsequently activated (dried) in an oven at 110°C for 30 minutes or more.

Sample application on the TLC plate is similar to that followed for paper chromatography, except that no pencil line is drawn. The plate after applying the sample and standards spots is developed in a tank using a suitable solvent. The ascending type assembly for TLC is shown in the Figure 7.8.

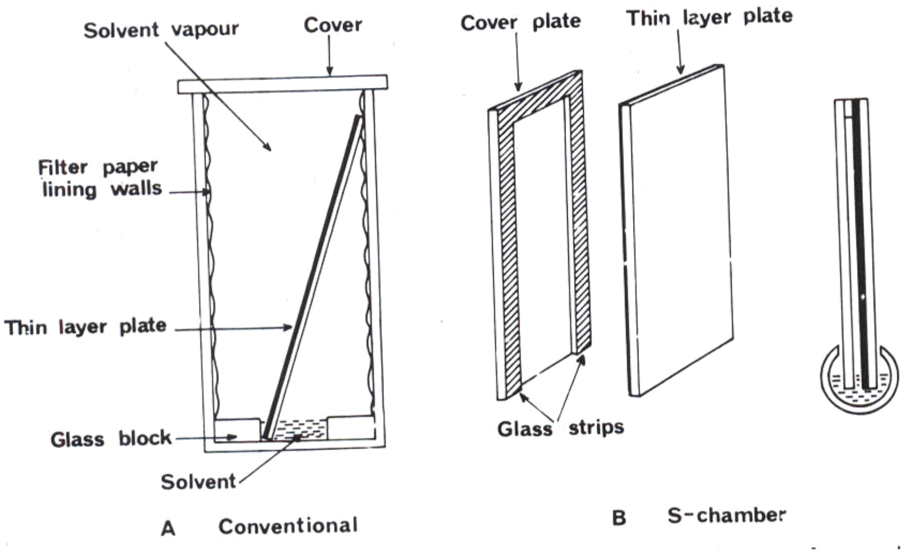

Figure 7.8: Ascending development chambers for TLC

TLC has certain advantages over paper chromatography. They are:

- TLC is far quicker than paper chromatography.
- As the support material used in TLC is truly inert unlike cellulose of filter paper, it is possible to use highly corrosive reagents for detection of components.
- TLC requires much smaller amount of sample and hence more sensitive than paper chromatography.

TLC is widely used for detection and identification of synthetic colours in foods, aflatoxin, pesticide residues besides most other substances mentioned under paper chromatography.

7.4.5 Column Chromatography

Until recently, column chromatography has been mostly employed for sample clean up (purification) prior to analysis by other methods. However, in some cases it is also used as an analytical tool and with the development of high sensitivity detectors, it has now evolved into **high performance liquid chromatography (HPLC)** having several applications.

The basic equipment for column chromatography is very simple. It consists of a vertical glass tube containing the inert material packed fairly firmly. The glass columns used are usually about 30 cm long and 1 cm internal diameter, although much longer and wider columns are used for specific purposes. The lower end of the column is tapered where a sintered disc is fixed or glass wool is placed to prevent the packing material from falling down.

Filling of the column with the packing material is a critical step. Care should be taken to fill the column firmly and evenly. The nature of the column filling material depends on the particular application. It could be alumina, silica gel, ion exchange resin, Sephadex gels, etc.

The filled column is fixed to a solvent (eluent) reservoir to hold the required solvent. A typical assembly is shown in the following Figure 7.9.

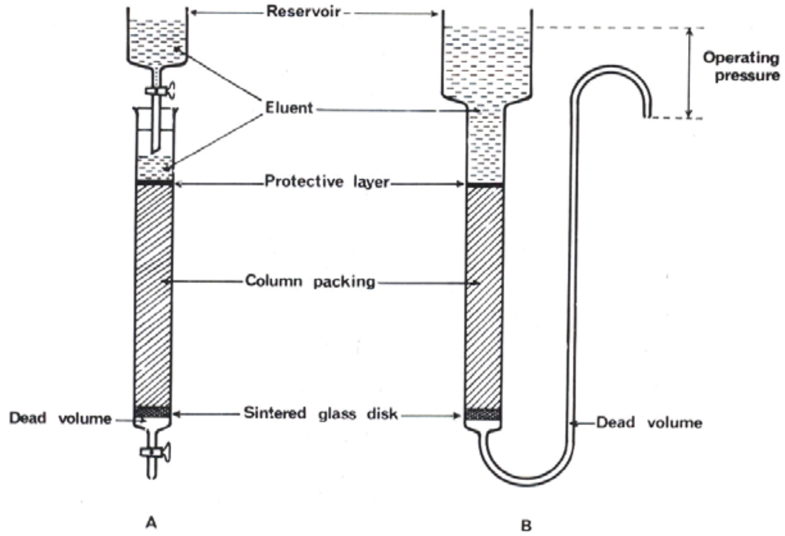

Figure 7.9: Column arrangement for liquid chromatography

After packing the column, it is washed with the intended solvent in order to wash out any impurities that may have been present in the packing material. At the top of the packing, a piece of glass wool is placed as a protective layer.

The sample is applied to the top of the column in a small volume of solvent drop by drop. The sample is allowed to penetrate into the packing material. Flow of the eluent through the column is called **elution.** Elution is normally achieved by gravity, although it may be necessary to facilitate flow by use of pumps or inert gas pressure. Flow rates of eluents for different applications have been standardised. However, flow rates of about 1 ml /min is normal.

For coloured compounds, the movement of coloured bands can be seen and each band can be collected separately in tubes and analysed. For colourless compounds, number of fractions have to be collected and analysed.

A number of methods are available for column chromatographic separation of food components. Separation of carotenoid pigments is an important method followed even today. Amino acids are separated on ion exchange columns. Peptides can be separated on Sephadex columns.

7.4.6 High Performance Liquid Chromatography

In the conventional column chromatography, the flow rate of mobile phase is usually by gravity. Therefore, to maintain satisfactory flow, the particle size of the inert column packing materials cannot be very small. Unfortunately, to get good resolution (separation) of sample mixture, very low particle size packing material is required. Systems have now available which can create pressures of the order of 600 atm. At that pressure, adequate flow rates are obtained even with packing particle as small as 2 to 3 μm in diameter. Along with this development, several detection systems were also adapted for use with liquid chromatographic columns. Liquid chromatography using these high-efficiency columns at high pressures has come to be known as **High-Performance Liquid Chromatography (HPLC)**.

Most HPLC columns are fabricated from stainless steel tubing. Usually the columns are 10 to 50 cm long with an inside diameter of 2-10 mm. The packing material used have diameter in the range of 3 to 10 μm. The detectors used in HPLC belong to one of the four basic principles viz. UV absorption, fluorescence, refractive index or conductance.

7.4.7 Gas Chromatography

In this section you will learn the details of gas-liquid chromatography, which is one of the most widely used analytical technique today. As mentioned earlier, gas-liquid chromatography is usually shortened as gas chromatography or merely GC.

There are a number of reasons why GC has become very popular in analytical work. Firstly, GC permits separation of complex mixtures including those containing closely related homologues and isomers. Secondly, it is relatively simple to prepare samples for analysis because unlike for other analytical methods, GC does not require extensive purification of the sample. The only requirement (may be a draw back) is that the components of the sample should be reasonably volatile.

The instrument used for gas chromatographic work is called a gas chromatograph. The modern gas chromatograph is a very complicated instrument. However, all gas chromatographs have a few key components, which is illustrated in the following Figure 7.10.

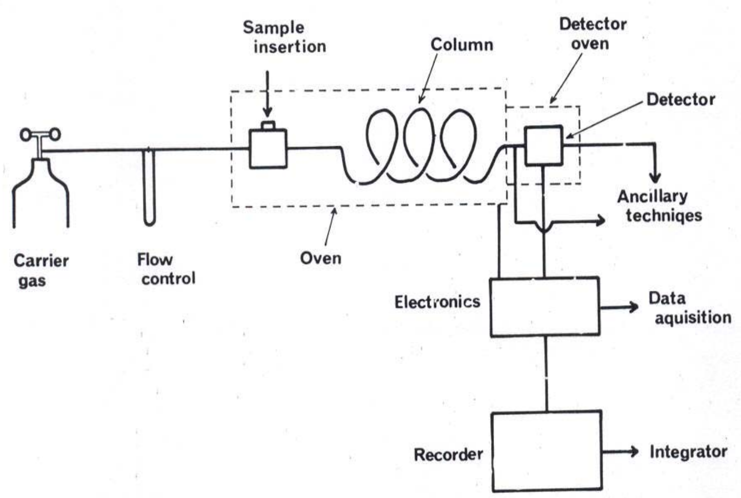

Figure 7.10: Basic components of a gas chromatograph

It can be seen from the diagram that a gas chromatograph has four major components viz. i) carrier gas supply system, ii) sample insertion (injection) system, iii) column assembly, and iv) detector and readout device.

Carrier Gas Supply System

The carrier gas used, which is the mobile phase in GC, must be chemically inert. These include helium, argon, nitrogen, carbon dioxide and hydrogen. The choice of the gas is decided to a great extent by the detector used. The gas supply assembly consists of the gas cylinder and gas flow meters. Gas flow rates play important role in the performance of a GC. Therefore, the gas flow rate is one of the parameters defined in GC procedures. The average gas flow rates for packed columns are in the range of 25 to 150 ml/ min and 1 to 25 ml/ min for capillary columns. You will be learning more about different types of columns subsequently. A soap bubble meter located at the end of the column is used to measure the gas flow rate.

Sample Injection System

Sample injection system has a sample injection port and a vaporizer. For efficient separation of sample components, it is necessary to introduce a small size sample into the column as a 'plug' of vapour. Usually a micro syringe is used for the purpose. The volume injected range from <1 to 20 μl. The sample vaporizer is usually maintained at a temperature of $50^{o}C$ above the boiling point of the least volatile components of the sample. The flow splitter allows the passage of only the quantity of the sample necessary for good resolution and the remaining is let out.

Column Assembly

Two general types of columns are used in GC. They are packed columns and open tubular or capillary columns. Packed columns are made of 1 to 10 m or longer stainless steel tubing having 1.5 to 5 mm internal diameter. Usually they are coiled for compactness. Capillary columns are much longer ranging from 10 to 100 m having very small diameter of the order of 0.1 to 0.5 mm. They are usually made of glass or silica.

The solid support in a packed column serves to hold the liquid stationary phase in place so that as large a surface area as possible is exposed to the mobile phase. The most widely used support material is prepared from diatomaceous earth. The particle size of the support material is usually in the range of 60 to 100 mesh.

Capillary columns are of two basic types viz. wall-coated open tubular (WCOT) and support–coated open tubular (SCOT). In WCOT columns, the inside of the capillary is coated with the stationary phase. In the SCOT columns, the inner surface of the capillary is coated with a thin film of the support material such as diatomaceous earth and over which the stationary phase is applied. Due to coating of the support material, SCOT columns can hold several times more of the stationary phase than in WCOT columns. Therefore, the efficiency of the SCOT columns is better than WCOT column.

Stationary Phase in the Column

The stationary liquid phase used in GC columns (both packed and capillary) are of different types. They are selected based on the nature of the compounds separated on the column. Some of the stationary phase substances are listed below.

Material	Trade name	Common application
Polydimethyl siloxane	OV-1, SE-30	Hydro carbons, steroids, polynuclear aromatics etc.
Poly (phenyl methyl) siloxane	OV-17	Pesticides, glycols, steroids, etc.
Poly (phenyl methyl dimethyl) siloxane	OV-3, SE-52	Fatty acid methyl esters, alkaloids, halogenated comps, etc.
Poly (trifluorophenyl dimethyl) siloxane	OV-210	Chlorinated aromatics, nitro aromatics, alkyl substituted benzenes, etc.
Poly (dicyanoallyl dimethyl) siloxane	OV-275	Poly unsaturated fatty acids, free acids, alcohols, etc.
Polyethylene glycol	Carbowax-20M	Free acids, alcohols, esters, essential oils, glycols, etc.

Detectors

Like in any chromatographic separation process, in GC also, the separated compounds have to be detected and quantified if necessary. An ideal detector should have some of the following characteristics.

- Adequate sensitivity.
- Good reproducibility.
- Wide range of linear response to analyte concentrations.
- Detection with out destroying the sample.
- Response to all types of compounds.

Unfortunately, an ideal detector is yet to be developed. Therefore, for different purposes, different detectors are used. There are a few types of detectors; two of the important ones are described below.

Flame Ionisation Detector (FID)

FID is one of the most widely used detectors for GC. In a flame ionisation detector, the effluent from the GC column is mixed with hydrogen and air and ignited electrically. When organic compounds are burnt at the high temperature, they produce ions and electrons that can conduct electricity through the flame. The current produced is amplified and measured.

Thermal Conductivity Detector (TCD)

TCD is based on the principle that the thermal conductivity of a gas stream is changed by the presence of analyte molecules. The sensing element in a TCD is an electrically heated element (platinum, gold or tungsten) whose temperature at constant electric power depends on the surrounding gas. The thermal conductivities of helium and hydrogen are about six times greater than those of most organic compounds. Therefore, in the presence of even traces of organic materials, a relatively large decrease in the thermal conductivity of the column effluent takes place. Consequently, the detector undergoes a marked increase in temperature. One major advantage of TCD as against FID is that it is non-destructive meaning that the compounds separated are not disintegrated and hence can be used for further analysis if required. Besides, TCD can detect both organic and inorganic compounds and hence has a wider range.

Signals from the detector are amplified and recorded by suitable electronic instruments. The output in the form of a graph having different peaks for the components is called a **gas chromatogram**. The chromatogram also provides the retention times, height and area of each peak.

Applications of GLC

Even though, GC is an excellent tool for tentative identification of components of a mixture, confirmation of their identity is rather difficult. Therefore, an important trend has been in combining the remarkable fractionation qualities of GC with the superior identification properties of such instruments as **mass spectrometer (MS)**, **infrared (IR)** and **nuclear magnetic resonance (NMR) spectrometers**. Mass spectrometer is very complicated and not meant for routine analytical purposes, hence will not be described in this unit.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is chromatography?

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2. Explain high-performance chromatography.

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3. Enumerate the key components of a gas chromatograph.

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7.5 LET US SUM UP

Modern analytical methods demand very accurate determination of mass. Consequently, considerable developments have taken place in increasing the sensitivity and simplicity of the analytical balance. This resulted in the modern single pan mechanical balance which can weigh with an accuracy even of ± 0.001 mg. Simultaneously, development in electronics have resulted in the evolution of electronic balances which have done away with the knife-edges which are the critical and wearable components of mechanical balances.

Measurement of pH of food systems is very important for various reasons. PH indicators based on colour change of certain chemicals have obvious drawbacks. Potentiometric method for the determination of pH is more reliable. The development of the glass electrode is one of the major breakthroughs in the instrumentation for pH measurement.

Chromatography, which started mainly as a separation technique, has assumed much more importance in food analysis. In addition to the simple techniques like column, paper and thin layer chromatography, gas chromatography and High-performance liquid chromatography have become very powerful tools for qualitative and quantitative analysis of food products.

7.6 KEY WORDS

Mass	:	Invariant measure of the amount of matter.
Weight	:	Force of attraction between an object and earth.
Chromatography	:	Writing in colours or separation of a mixture of compounds based on adsorption and partition.
Partition	:	Distribution of solutes between two phases.
Retention factor	:	Ratio of distance moved by the solute to distance moved by the mobile phase.
Eluent	:	Solvent used as the mobile phase.
Carrier gas	:	Gas used as the mobile phase in gas chromatography.
FID	:	Flame ionisation detector.
TCD	:	Thermal conductivity detector.

7.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

- Invariant measure
- Dependent on gravitational force

2. Your answer should include the following points:

- Single pan and set of weights on one end of beam and counter weight at the other end
- Air damper
- Optical system

3. Your answer should include the following points:

- No beam
- No knife-edge
- Servo system

4. Your answer should include the following points:

- Ionisation of water
- Ionisation constant of water
- pH = - log [H^+]

5. Your answer should include the following points:

- Glass electrode
- Calomel or silver-silver chloride reference electrode
- Potentiometer

Check Your Progress Exercise 2

1. Your answer should include the following points:

- Separation of the components of a mixture
- Adsorption
- Partition

2. Your answer should include the following points:

- Liquid column chromatography at high pressure
- Electronic detectors

3. Your answer should include the following points:

- Carrier gas
- Sample injection system
- Column assembly
- Detector and readout device

7.8 SOME USEFUL BOOKS

1. Hagris, L.G. (1988) Analytical Chemistry, Prentice Hall, New Jersey.

2. Mac Leod, A.J. (1973) Instrumental Methods of Food Analysis, Elek Science, London.

3. Skoog, D.A., and Leary, J.J. (1992) Principles of Instrumental Analysis, Saunders College Publishing, Florida.

UNIT 8 ANALYTICAL INSTRUMENTATION BASED ON ELECTROMAGNETIC RADIATION

Structure

8.0 OBJECTIVES

After reading this unit, you should be able to:

- explain the properties of electromagnetic radiation;
- describe different types of spectroscopic methods;
- describe the components of a colorimeter and spectrophotometer;
- differentiate between atomic absorption and emission spectroscopy; and
- explain the principle and instrumental details of refractometer and polarimeter.

8.1 INTRODUCTION

Majority of the modern instrumental methods of analysis are based on interaction of electromagnetic radiation with matter (elements and molecules). They include emission, absorption, scattering, fluorescence, refraction, reflectance and rotation of radiation. You have learnt reflectance colour measurement of materials like fruits in the previous unit.

Spectrometry is a general term describing various methodologies dealing with the production, use and measurement of electromagnetic radiant energy or radiation. Electromagnetic radiation can interact with matter to produce measurable signals, which are made use of for qualitative and quantitative measurements. In this unit, you will be learning about some of the instruments based on these principles. In order to understand the nature of these interactions, it is necessary to have some basic knowledge of the propagation of radiation.

8.2 PROPERTIES OF ELECTROMAGNETIC RADIATION

Electromagnetic radiation is a type of energy that is transmitted through space at enormous velocities. For simplicity of understanding, the transmission can be viewed to be of a transverse waves consisting of discrete energy packets called photons. The waves oscillate in all the planes perpendicular to the direction of propagation.

There are a few important terminologies associated with the propagation of electromagnetic radiation. They can be explained easily with the aid of the waves of a plane-polarised light shown below (Figure 8.1). Plane polarised light (radiation) is one in which the wave oscillation is only in one plane. You will learn more about polarisation later.

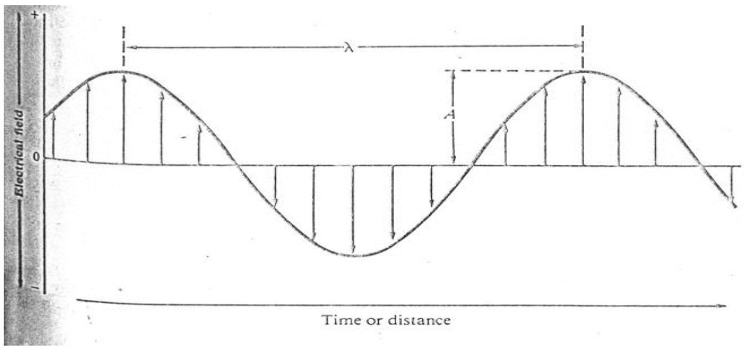

Figure 8.1: A beam of plane polarised monochromatic radiation of wavelength λ and amplitude A

The **amplitude, A** of the wave is defined as the maximum height of the wave. The length of one wave or the distance between two successive maxima or minima of a wave called the **wavelength, λ** of the radiation. The reciprocal of the wavelength, or the number of waves per unit length is called the **wave number, ν.** The time required for one wave to pass a fixed point in space is called the **period, p** and its reciprocal, the **frequency, υ** which is the number of waves passing a fixed point per unit time. A simple relationship exists between the length of a wave (wavelength) and the time required for it to move past a fixed point in space. This relationship says that the product of the wavelength and frequency equals the **velocity of propagation of the wave, c.** In vacuum, the velocity of propagation of radiation (usually referred to as **speed of light**) is approximately 3.0×10^8 m/s. The velocity of radiation in any other medium is always less because of interaction with matter. Since the radiant frequency is invariant and fixed by the source, the wavelength of radiation decreases as it passes from vacuum to a medium containing matter. In air, the velocity is only marginally less (0.03%). Chemists in characterising radiant energy most often use wavelength and frequency.

The power, P of radiation (frequently also called intensity) is the energy of beam that reaches a given area per second. P is related to the square of amplitude, A. Electromagnetic radiation is continuous over all possible wavelengths. It is sub divided according to how the radiation reacts with matter. The visible portion of the spectrum i.e. those wavelengths to which the human eye produces a sensation called colour, is only a tiny part of the spectrum (750 to 380 nm) as shown in the following Figure 8.2.

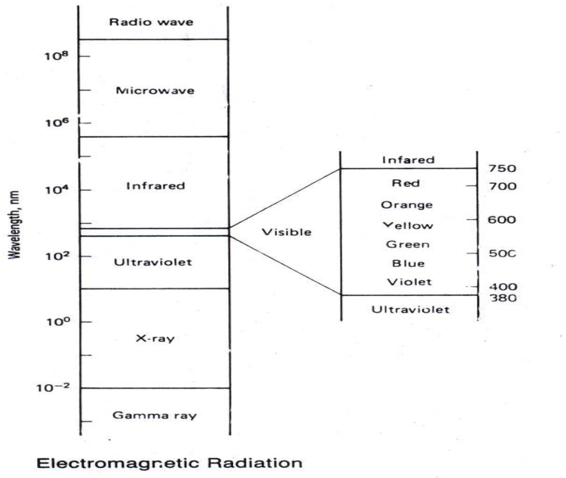

Figure 8.2: The electromagnetic spectrum

You have learnt that the interactions of electromagnetic radiation with matter cause certain responses (phenomena). Optical spectroscopic methods are based on measuring these responses.

8.3 SPECTROSCOPY

Historically spectroscopy referred to a branch of science in which visible or ultraviolet light is resolved into its component wavelengths, thus producing spectra, which were then used for theoretical studies on the structure of matter or for qualitative and quantitative analysis. However, with passage of time, the meaning of spectroscopy has broadened to include other types of electromagnetic radiations also. Currently, spectroscopy even includes studies with other types of radiations including ions (mass spectrometry), electrons (electron spectroscopy), and sound waves (acoustic spectroscopy).

Among various interactions between radiation and matter, absorption of radiation is the most important for analytical work. Visible and ultraviolet radiations are the most widely used for the purpose. Therefore, visible and ultraviolet absorption spectroscopy will only be dealt with in detail here.

8.3.1 Absorption of Radiation

In spectrometry, absorption is a process in which a chemical species in a transparent medium selectively attenuates (decrease the intensity of) certain frequencies of electromagnetic radiation. The absorbing characteristics of a chemical species are described by means of an absorption spectrum, which is usually a plot of some function of the attenuation versus wavelength, frequency or wave number.

In absorption spectrometry, one encounters both atomic absorption and molecular absorption. Atomic absorption relates to absorption of radiation by atoms and ions (especially the metals) and the consequent responses. Methods based on this phenomenon fall under **atomic absorption spectroscopy (AAS)**. The second is called molecular absorption spectroscopy, which has found maximum application in qualitative and quantitative analysis.

Molecular Absorption Spectroscopy

You have learnt that a beam a radiant energy is reduced in power as it passes through a solution containing absorbing substances. The attenuated radiation is transmitted. At this stage it may be of interest to know why a coloured solution has a particular colour. For example a red coloured solution is red not due to the molecules of the solute impart red colour to the solvent. Instead the solute molecules absorb the green component of the white radiation and transmit the red component. Thus, green colour is called the complimentary colour for red. You will learn subsequently in visual colorimetry the complimentary colours are used to measure the absorption characteristics of the coloured solutions.

Wave-length range (nm)	Colour	Complimentary colour
400 – 435	Violet	Yellow – Green
435 – 480	Blue	Yellow
480 – 490	Blue-green	Orange
490 – 400	Green-Blue	Red
500 – 560	Green	Purple
560 – 580	Yellow-green	Violet
580 – 595	Yellow	Blue
595 – 650	Orange	Blue – Green
650 – 700	Red	Green – Blue

Important terms used in Absorption Spectroscopy

The terms can be explained using the simple diagram below (Figure 8.3):

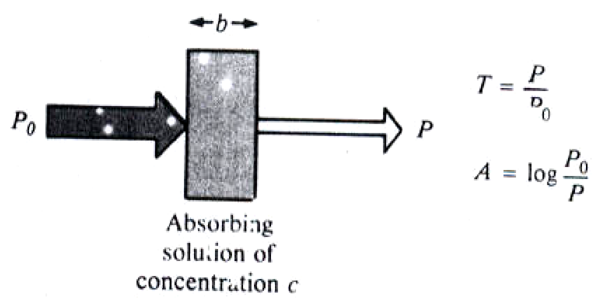

Figure 8.3: Attenuation of radiation by an absorbing solution

The Figure shows a beam of radiation before and after it has passed through a layer of solution with a **thickness, b cm** and a **concentration of c** of an absorbing solution. The power of the beam is attenuated from P_0 to P. The **transmittance, T** of the solution is defined as the fraction of the incident radiation transmitted by the solution.

$$T = P/P_0$$

Transmittance is usually expressed as a percentage (%T).

Absorbance, A of a solution is defined by the expression

$$A = -\log T = \log P_0/P = \log 1/T \text{ or } \log 100/\%T$$

$$A = \log \frac{P_0}{P}$$

$$\Rightarrow \quad A = \log P_0 - \log P$$

Since P_0 always set at 100% and log P is % T

$$A = \log 100 - \log \% P$$

$$A = 2 - \log \% T$$

i.e. $$A = 2 - \log \%T$$

Please note that in contrast to transmittance, the absorbance of a solution increases as the attenuation of the beam increases.

Relationship between absorption and concentration

The relationship between the amount of radiation absorbed or transmitted and the amount of absorbing substance is called Beer's Law or sometimes Beer's-Lambert Law.

$$A = \log P_0/P = abc$$

Where **a** is a proportionality constant called the absorptivity and **b** is the path length of the radiation through the absorbing media and c its concentration. When the concentration is expressed in moles per litre and b is in cm., they absorptivity is called **molar absorptivity** ε i.e.

$$A = \varepsilon bc$$

Where ε has the units of $l\ cm^{-1}\ mol^{-1}$

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain the terms wavelength and frequency of electromagnetic radiation.

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2. What is spectroscopy?

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3. Differentiate between molecular absorption and atomic absorption spectroscopy.

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4. Explain Beer's law.

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5. Analyst found that the minimum concentration of 3-aminotriazole (M.W = 84) that could be determined in meat product was 0.05 ppm. At this concentration the absorbance of the coloured reaction product was 0.02 with 1 cm all thickness. What is the molar absorptivity E of this reaction.

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Instruments for Absorption Spectroscopy

Absorption spectroscopic instruments have 5 basic components i) a source of radiant energy, ii) a wave-length selector that allows the radiation of a restricted wave-length region, iii) one or more sample holders, iv) a radiation detector or transducer which converts radiant energy to electrical signal, and v) signal processor and read-out (Figure 8.4).

Figure 8.4: Basic components of a spectrometer

Radiation sources: The basic requirements of a radiation source for spectroscopic studies are (1) should generate a beam of radiation with sufficient power for easy detection and measurement and (2) its out-put power should be stable for reasonable periods. No single source is suitable for all the spectral regions of interest to analytical work. For the visible spectroscopy, the most common energy source is a tungsten filament lamp which has an out-put (325 nm to 3000 nm) which covers the entire visible region of the spectrum and also part of the ultra violet and infrared regions. For ultra violet spectroscopy, the preferred energy source is deuterium discharge lamp which has an out-put in the range of 160 nm to 380 nm.

Wavelength selector: Since the radiation sources are continuous, it is necessary to select the required wavelength at which the measurement is to be made. As it is practically impossible to isolate a single wavelength, a very narrow band of wavelength is usually isolated. Two types of wavelength selectors are available, namely, filters and monochromators.

Filters: Filters operate by absorbing all but a restricted band of radiation from a source. A filter is characterised by its nominal wavelength, maximum percent band width and its effective bandwidth. (Figure 8.5)

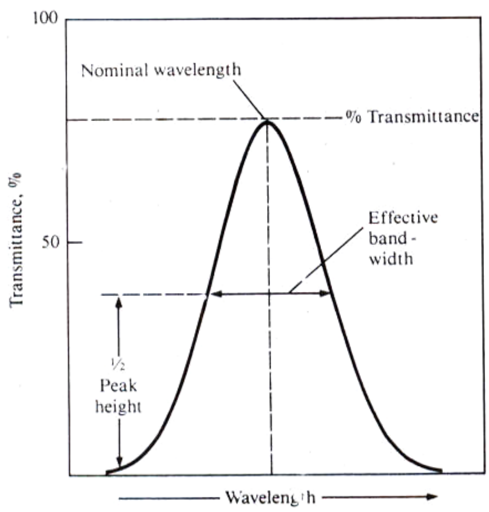

Figure 8.5: Output of a typical filter

Absorption filters are the most common type of filters. Absorption filter consists of a coloured glass piece that removes part of the incident radiation by absorption. Obviously, absorption filters are limited in application to the visible region.

Monochromators: Monochromators have mostly replaced filters in spectrometers due to their ability to produce very narrow band of wavelength over a considerable spectral range from radiation source. Such measurements are called spectral scanning. Monochromators as the name implies are capable of passing radiation of almost a single wavelength called monochromatic radiation. The components of a monochromator are i) an entrance slit that provides a rectangular optical image of the radiation ii) a collimating lens or mirror which produces a parallel beam of radiation iii) a prism or grating that disperses the radiation into its component wave-lengths iv) a focusing element that reforms the image of the slit and focuses it on a planar surface called a focal plane and v) an exit slit that isolates the desired spectral band. The following figure shows the assembly for the two types of monochromators.

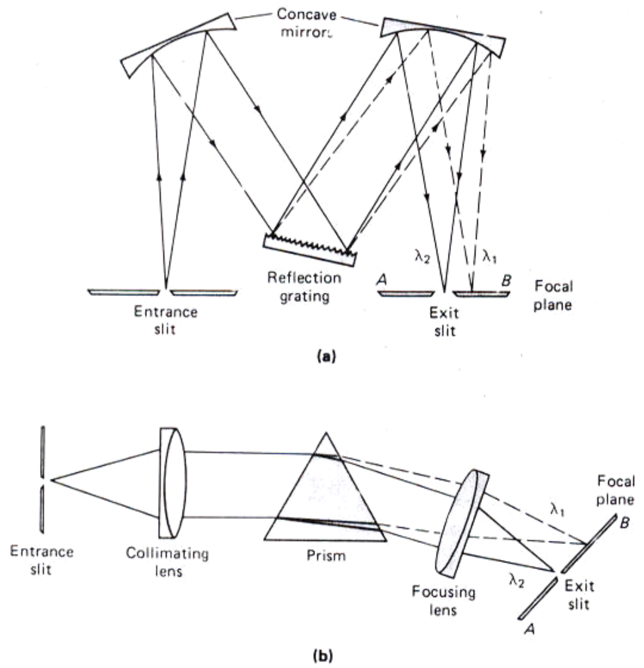

Figure 8.6: Two types of monochromators

Sample holders: Sample holders are called cells or cuvets, which come in a variety of shapes and sizes appropriate for various instruments and experiments. The rectangular cell of 1 cm light path is the most widely used. Glass cells are used for measurements with visible radiation but cannot be used with ultra violet because of their strong absorption. Quartz or fussed silica cells, though more expensive are suitable for both UV and visible spectrometry.

The remaining two components of a spectroscope are the radiation detector and read-out device. The components of spectroscope described above have been assembled in various ways to produce a number of designs of instruments. Some are simple but other are very sophisticated. Therefore, their costs also vary widely. No single instrument is best for all purposes and selection must be based on the type of work for which the instrument is intended and by the economics of its application.

There are some common names for spectroscopic instruments. A **photometer** is a simple instrument that can be used for absorption, emission and fluorescence measurements with ultra violet, visible or infrared radiations. A photometer is distinguished by its use of absorption or interference filters for wavelength selection and a photoelectric device for measurement radiant power. Instruments used for absorption measurements with visible radiation are sometimes called **photoelectric colorimeter** or simply **colorimeter**. A photometer that is employed for fluorescence measurements exclusively is called a **fluorometer**. A spectrometer is a spectroscopic instrument equipped with a monochromator. A spectrometer equipped with a photo transducer is called a **spectrophotometer**. Fluorescence spectrometers are often called **spectrofluorometers**.

Spectrophotometers: Numerous spectrophotometers are available to choose from. Some are designed for the visible region only, where as others are for both visible and ultraviolet regions. Spectrophotometers meant for the visible region are called **photoelectric colorimeters.** They can be used in the wavelength range of 380 to 800 nm. **Spectronic 20** is a typical commercial model of a photoelectric colorimeter (Figure 8.7).

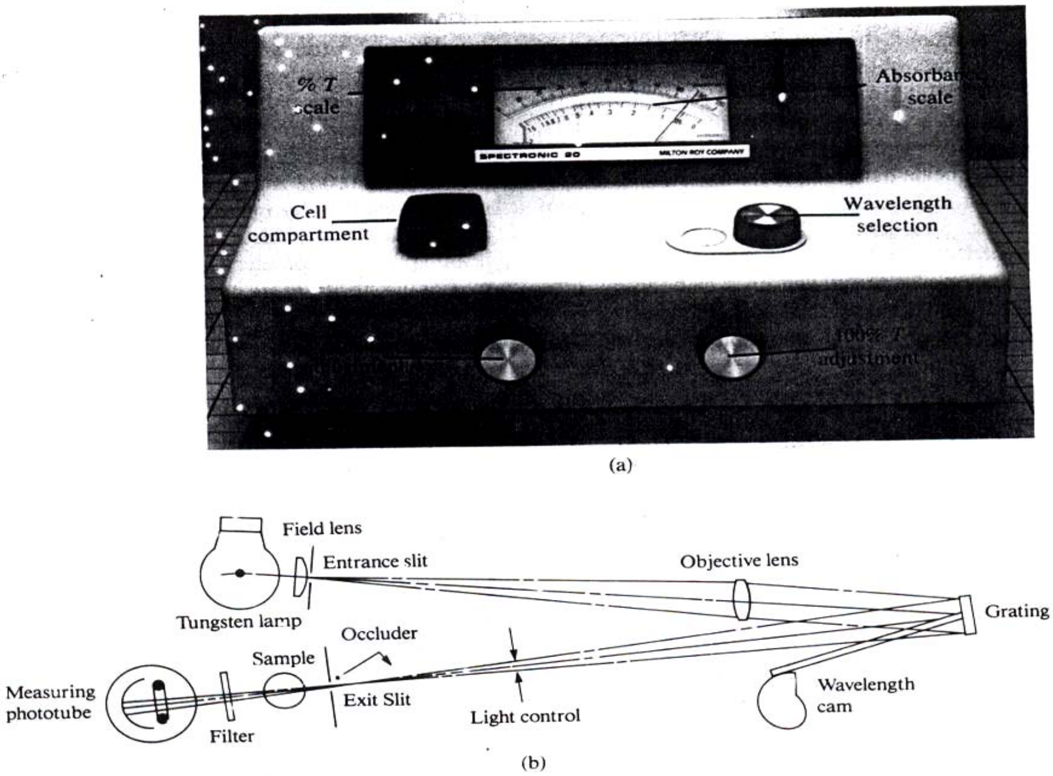

Figure 8.7: a) Spectronic 20 spectrophotometer, b) its optical diagram

The instrument employs a tungsten filament lamp light source, and a reflection grating for wavelength selection. The selected wavelength of radiation is passes through the sample tube and to a phototube. The amplified electrical signal then powers a meter calibrated in % transmittance and absorbance.

Single and double beam spectrophotometers: Single beam instruments are simple and less expensive than double beam instruments. In this type of instruments, the cells containing reference and sample solutions have to be placed alternatively to tale measurements. Double beam spectrophotometers have two optical paths, which pass through the sample and reference solutions simultaneously. Such instruments also have provision for measurement of absorbance or transmittance of solutions continuously.

8.3.2 Atomic Spectroscopy

In the previous section, you have studied molecular absorption spectroscopy. Atomic spectroscopy is based on absorption, emission and fluorescence phenomena. Atomic spectroscopy is used for the qualitative and quantitative determination of more than 70 elements. Sensitivities of atomic methods are very high of the order of parts- per- million (ppm) to parts- per- billion (ppb). The reason that thermal emission methods are little used for determining molecular species is that most molecules decompose at the temperatures required for producing atomic spectra.

Atomic absorption spectroscopic methods are characterised on the basis how the sample is atomised. The most convenient and common method followed is by using a suitable flame. Therefore, the instrumentation based on flame atomisation only will be discussed in this section. There are three methods under flame atomisation, viz. i) atomic absorption spectroscopy (AAS), ii) atomic emission spectroscopy (AES), and iii) atomic fluorescence spectroscopy (AFS). Among the three, AAS and AES have a lot of similarities, but it is important to know the differences.

Atomic Absorption and Emission Spectroscopy

Both AAS and AES are extremely important and valuable analytical techniques. It is well known that coloured radiations are produced when salts such as those of sodium, calcium, copper etc. are introduced into normal flames. Talburt investigated similar flame spectra of strontium, and lithium. In 1960, and 1961 Bunsen and Kirchoff discovered the elements caesium and rubidium by observing their flame spectra. It is the emission of such characteristic radiation and the determination of the intensity of this, which form the basis of atomic emission photometry. Atomic absorption spectroscopy deals with the external radiation absorbed by an element in a flame under certain conditions.

Flame atomisation: The critical component of a flame spectrometer is the flame atomiser. A flame atomiser consists of a pneumatic nebulizer, which converts the sample solution into a mist that is then fed into a burner. The most common type of nebulizer is based on aspiration in which the sample is sucked through a capillary tube by a high-pressure stream of gas flowing around the tip of the tube.

Burning a fuel with air or an oxidant like oxygen or nitrous oxide produces the flame in the burner. Air fuel mixtures produce flame having temperature in the range of 1700 to 2400°C, which is suitable for exciting only alkali and alkaline earth metals. For heavy metals, fuel- oxygen or nitrous oxide flames, which produce temperature in the range of 2500 to 3100 ^{0}C, are required.

Emission and absorption spectra for both atoms and elementary ions are obtained from the flame. When atoms and ions are heated in a flame, they are excited to various stages of energy levels. The excited species on relaxation produces the emission spectra and the unexcited species can absorb energy from an external source for producing absorption spectra. The external source for producing absorption spectra is usually a hollow-cathode.

Hollow-cathode lamp: The most useful radiation source for AAS is the hollow-cathode lamp. It consists of a tungsten anode and a cylindrical cathode sealed in a glass tube containing an inert gas such as argon. The cathode is made up of or coated with the metal to be analysed. Application of a high potential across the electrodes causes ionisation of the argon and generation of a current. The argon cations migrate towards the cathode and strike with sufficient energy to dislodge some of the metal atoms producing an atomic cloud. Some of the metal ions in the cloud in the excited state emit their characteristic wavelengths as they return to the ground state. The emitted radiation is allowed to be absorbed by the unexcited atoms/ions of the same species in the flame and the extent of absorption is measured. Hollow-cathode lamp for a large number of elements is available. The development of the hollow-cathode is widely regarded as the single most important event in the evolution of atomic absorption spectroscopy. The remaining components of AAS or AES are similar to those present in molecular absorption spectrometers.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe the basic components of an absorption spectroscope?

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2. What is a monochromator?

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3. Differentiate between colorimeter and spectrophotometer.

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4. Describe a Hollow-cathode lamp.

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8.3.3 Refractometry

Refractometry involves the determination of the refractive index of a solution. It is applied to both qualitative and quantitative analysis such as identification of oils and fats, concentration of sugar solutions and total soluble solids content of fruit juices.

Refractive index is an important property of matter. You have already learnt about the propagation of light through vacuum and other media. Refractive index is defined as the ratio of the velocity of a radiation of a particular frequency in vacuum to the velocity in the medium under consideration. When a ray of light travels obliquely from one medium into another of different density, its direction is changed (bent) on passing through the interface between the two media. This phenomenon is called refraction. This phenomenon can be easily explained with the help of the following Figure 8.8.

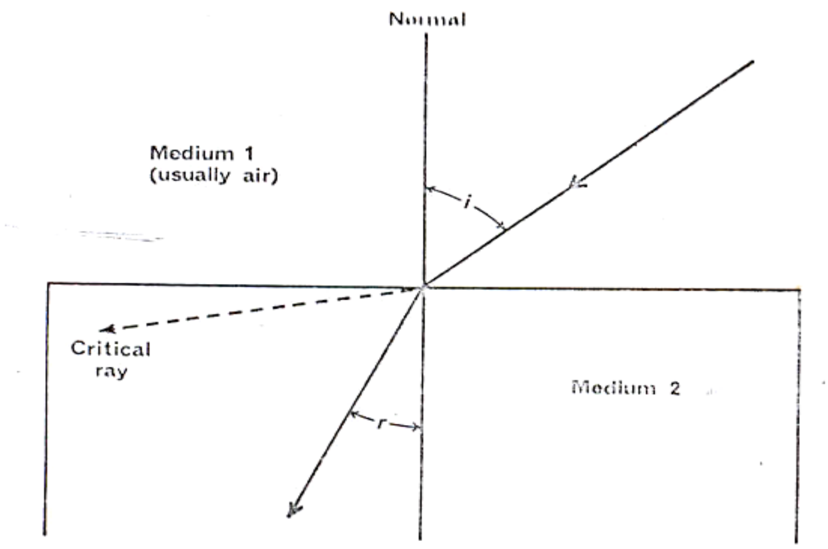

Figure 8.8: Refraction of light

The angle made by the incident ray in the first medium is called the angle of incidence, i and the corresponding angle in the second medium is termed the angle of refraction, r. sin i and sin r are directly proportional to the velocities of the radiation in the two media. Therefore, refractive index of the medium:

$$n = \frac{\sin i}{\sin r}$$

The refractive index of a medium is characteristic of that medium under constant temperature of measurement and the wavelength of the incident radiation. **Refractive index, n** of a medium is denoted by $\mathbf{n_D^{20}}$ meaning that it is measured using radiation of sodium D- line at 20°C. Water has a value of η_D^{20} of 1.3330. An instrument used to measure the refractive index (extent of bending of the radiation) of a medium is called a refractometer. The most important type of refractometer is the Abbe' refractometer.

Abbe' refractometer

A simplified diagram of the optical system of Abbe' refractometer is shown below (Figure 8.9).

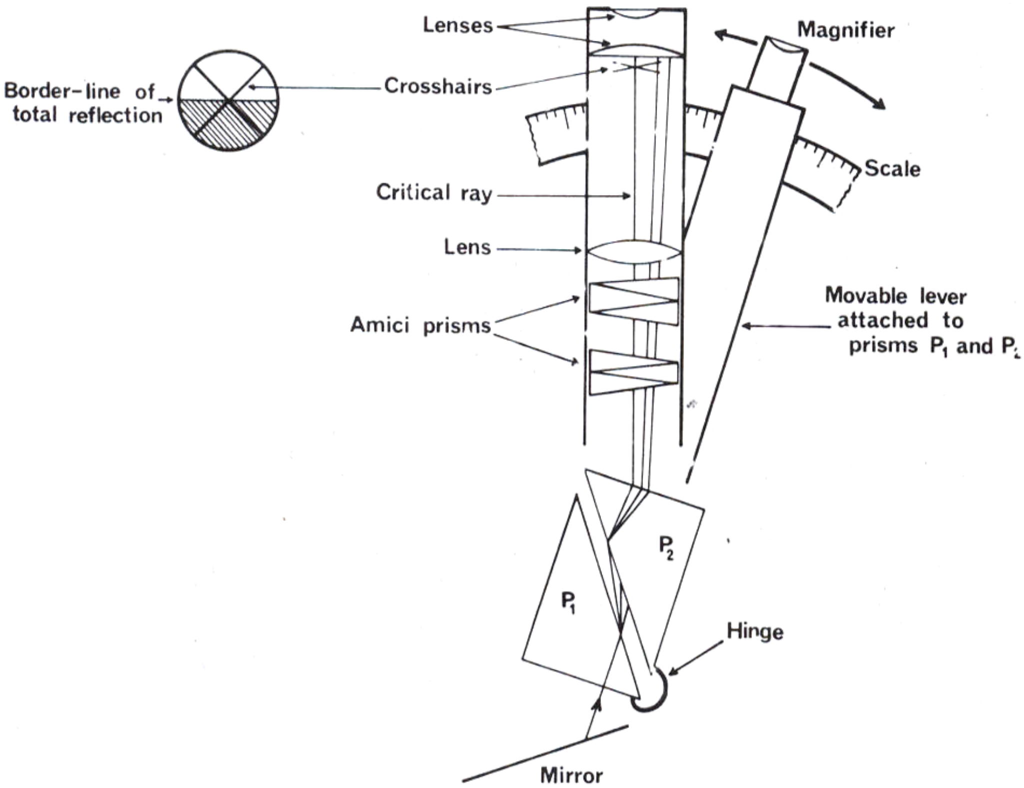

Figure 8.9: Abbe' refractometer

The most important component of the instrument is the double prism unit (P_1 and P_2). The unit can be rotated by means of a lever. At the other end, this lever moves over a fixed scale at which readings can be taken. The upper prism is made of a type of glass in which light has a velocity less than the velocity in any sample likely to be examined. The liquid sample is coated as a thin film between these two prisms. The upper prism is fixed while the lower one can be swung on a hinge to introduce sample and for cleaning.

White light entering the instrument is split by the two Amici prisms placed in the telescope of the instrument and only the sodium D-line is transmitted. Light falling on the polished surface of prism P_1 reflects an infinite number of rays through the liquid sample. The rays strike the surface of the upper polished prism, P_2 and are refracted. All light rays pass through the prism P_2, except those, which are parallel to the surface of the prism. The parallel rays are bent upwards and emerge from the prism at an angle, which is determined by the refractive index of the sample solution. The critical ray forms the border between light and dark portions of the field viewed by the observer. This border is aligned with the cross hairs of the eyepiece of the fixed telescope of the refractometer by slowly rotating the double prism unit. A fixed scale measures the angular relationship of the double prism to the telescope. Thus by moving the lever, the critical ray is scanned until it coincides with a fixed point in the instrument.

Usual Abbe' refractometer covers a range of refractive index either from 1.30 to 1.70 or from 1.45 to 1.84. The concentration of a known substance in a solution can be readily determined by measuring the refractive index of the solution. This is the basis of °Brix (% of sugar) measurement. Abbe' refractometer provides separate scale based on the same principle.

8.3.4 Polarimetry

Polarimetry involves the measurement of the optical rotatory power of a substance. This method can also be used for both qualitative and quantitative analysis. You have learnt about the optical rotatory properties (levo and dextro) of compounds especially sugars. This is the basis of saccharimetry.

You have also learnt about plane polarisation of light. Many substances are capable of rotating the plane polarised light. Such substances are said to be optically active. Examples are amino acids, sugars, steroids, terpenes etc. The extent to which the plane-polarised light is rotated by an optically active compound is dependent on the concentration of its solution and path length under constant conditions of temperature, wavelength of the polarised light and solvent used. Thus the specific rotation of a solution is given by:

$$[\alpha]_{\lambda}^{T} = \frac{\alpha}{dc}$$

where, $[\alpha]_{\lambda}^{T}$ is the specific rotation at temperature T and λ wavelength of radiation. The angle of rotation measured is α and c is the concentration of the solution (in g/ml) contained in a sample tube d decimetres in length. Figure 8.10 shows a diagrammatic arrangement of a polarimeter.

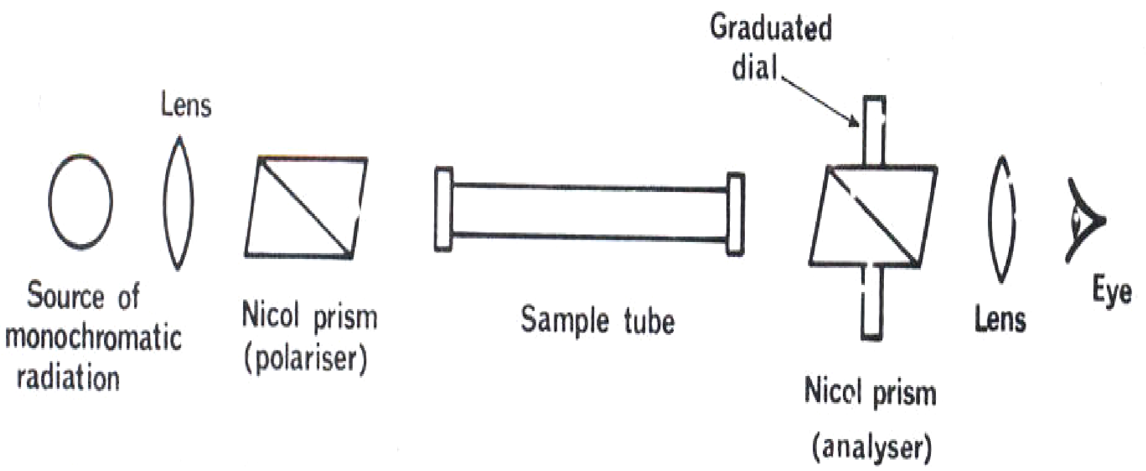

Figure 8.10: Components of a polarimeter

Monochromatic radiation from a source is passed through a Nicol prism, which polarises the radiation. Nicol prism is made of calcite or quartz crystal block cut diagonally in a special manner and cemented together. The polarised light passes through the sample when it is rotated. The analyser prism is another Nicol prism similar to the polariser prism. The prism is rotated to the extent of rotation of the radiation to allow it to be fully transmitted and observed by the human eye. The analyser is attached to a dial to indicate the number of degrees of rotation and direction of rotation.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is meant by the refractive index of a medium?

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2. Explain the components of Abbe' refractometer and how it is used to measure the refractive index of a solution.

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3. What is polarisation of light?

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4. Describe the components of a polarimeter and explain how it is used to determine the concentration of an optically active solute.

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8.4 LET US SUM UP

A number of instruments based on the interactions of electromagnetic radiations with food components are used for analysis and quality control. These interactions could be in the form of absorbance, emission, refraction, and rotation of radiation. Among the instruments, those based on absorption of radiation by solutions are widely used for qualitative and quantitative analysis of elements and compounds. While colorimeters are used in the visible range of radiation, spectrophotometers can be used with ultra violet, visible and infrared regions.

Atomic absorption and emission spectroscopy find application in the determination of elements, especially metal ions.

Refractometers are based on the principle of refraction of light radiation. Refractometer is a handy instrument for measuring the total soluble solids (^{o}Brix) of fruit products and sugar solutions.

Polarimeter is based on the principle of rotation of plane polarised light by a solution of optically active substance. A number of food components, especially oils, and sugars exhibit optical activity. Therefore, they can be easily determined using a polarimeter.

8.5 KEY WORDS

Wavelength	:	Distance between two successive waves.
Frequency	:	Number of waves passing a fixed point per unit time.
Beer's law	:	Relationship between amount of radiation absorbed and the concentration of solute in the solution.
Monochromator	:	An optical instrument to produce a narrow band of radiation.

8.6 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Distance between two successive wave maxima or minima
   - Number of waves passing a fixed point per unit time

2. Your answer should include the following points:

   - Study of the interactions of electromagnetic radiations with matter
   - Absorption spectroscopy
   - Emission spectroscopy
   - Fluorescence spectroscopy

3. Your answer should include the following points:

   - Absorption of radiation by molecules
   - Absorption of radiation by atoms and ions

4. Your answer should include the following points:

   - Relationship between amount of radiation absorbed and the amount of absorbing substance.

5. Your answer should include the following points:

   - **Hints:** Use formula A = Ebc, Ans.33600

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Source of radiant energy
   - Wavelength selector
   - Sample holders
   - Radiation detector

2. Your answer should include the following points:

   - Instrument to produce monochromatic radiation
   - Prism or grating

3. Your answer should include the following points:

   - Absorption measurement with visible radiation
   - UV, visible and IR

4. Your answer should include the following points:

   - Emits characteristic radiations of metals
   - Atomic absorption spectroscope

Check Your Progress Exercise 3

1. Your answer should include the following points:

   - Ratio of velocity of radiation in vacuum to the velocity in the medium
   - Ratio of sin i to sin r

2. Your answer should include the following points:

   - Double prism unit
   - Amici prism and telescope

3. Your answer should include the following points:

   - Restricting the oscillations to one plane
   - Optical activity

4. Your answer should include the following points:

   - Nicol prism
   - Sample tube
   - Measuring scale

8.7 SOME USEFUL BOOKS

1. Hagris, L.G. (1988) Analytical Chemistry, Prentice Hall, New Jersey.
2. Mac Leod, A.J. (1973) Instrumental Methods of Food Analysis, Elek Science, London.
3. Skoog, D.A., and Leary, J.J. (1992) Principles of Instrumental Analysis, Saunders College Publishing, Florida.

EXPERIMENT 1 DETERMINATION OF ASCORBIC ACID BY TITRIMETRIC AND COLORIMETRIC METHODS

Structure

1.1 INTRODUCTION

Fruits and vegetables are important sources of ascorbic acid (vitamin C). Ascorbic acid being unstable under different storage and processing conditions, it is important to know its residual content in food products. The most satisfactory chemical method of estimation is based on the reduction of 2,6-dichlorophenol indophenol by ascorbic acid. This can be performed either by titration or by colorimetric method. In this experiment you will be learning both the methods.

Objectives

After studying and performing this experiment, you should be able to

- prepare different types of food samples for ascorbic acid estimation;
- determine the ascorbic acid content by dye titration method; and
- determine the ascorbic acid content by xylene extraction and colorimetric method.

1.2 EXPERIMENT 1a: DYE TITRATION METHOD

1.2.1 Principle

2,6-dichlorophenol indophenol dye, which is blue in alkaline solution and red in acid solution, is reduced by ascorbic acid to a colourless form. The reaction is quantitative and can be performed by titration. This reaction is practically specific for ascorbic acid in fresh fruits and vegetables. Sulphur dioxide present in products like squashes can deduce the dye and thus interferes in the estimation. Condensing SO_2 with formaldehyde can eliminate this interference.

1.2.2 Requirements

Apparatus/Glassware

Microburette, 10 ml capacity with 0.05 ml sub-graduations

Burette stand

Volumetric flask, 100 ml

Pipette, 1 ml

Conical flask, 100 ml

Analytical balance, 0.1 mg sensitivity

Whatman No.1 filter paper circles

Glass funnel, 2" dia.

Chemicals and Reagents

i) 3% (w/v) Metaphosphoric acid (HPO_3): Prepare by dissolving the sticks or pellets of HPO_3 in distilled water.

ii) Ascorbic acid standard: Weigh accurately 100 mg of L-ascorbic acid and make up to 100 ml with 3% HPO_3 solution. Dilute 5 ml to 50 ml with 3% HPO_3 solution (1 ml = 0.1 mg of ascorbic acid).

iii) Dye solution: Dissolve 50 mg of the sodium salt of 2,6-dichlorophenol indophenol in approximately 150 ml of hot distilled water containing 42 mg of sodium bicarbonate. Cool, filter and dilute with distilled water to 200 ml. Store in a refrigerator and standardize every day.

iv) Formaldehyde, 40% solution.

v) Conc. Hydrochloric acid.

1.2.3 Procedure

Standardization of Dye

Pipette out 5 ml of the standard ascorbic acid solution into a 100 ml conical flask and add 5 ml of the 3% HPO_3 solution. Fill the microburette with the dye solution. Titrate the ascorbic acid solution with the dye solution to a pink colour, which should persist for 15 sec. Note the Titre value. Calculate the dye factor.

Volume of ascorbic acid solution taken for titration = 5 ml

Volume of dye solution required (titre) = V = ----- ml

Dye factor = mg of ascorbic acid per ml of the dye

Since 5 ml of the standard ascorbic acid solution contains 0.5 mg ascorbic acid:

$$\text{Dye factor} = \frac{0.5}{\text{Titre}} = \frac{0.5}{V} = \text{mg ascorbic acid per ml dye}$$

Preparation of Sample

Juices and liquid products: Take 10-20 g sample and make up to 100 ml in a volumetric flask with 3% HPO_3 solution. Filter through a Whatman No. 1 filter paper.

Solid or semi-solid products: Blend 10-20 g sample with 3% HPO_3 solution and make up to 100 ml in a volumetric flask with 3% HPO_3 solution. Filter through a Whatman No. 1 filter paper.

Titration

Pipette out 2-10 ml of the sample extract into a 100 ml conical flask and titrate against the dye solution as above. The volume of the sample should be such that the tire value is in the range of 3-5 ml.

If the sample contains sulphur dioxide, to the pipetted out sample extract add 1 ml of the formaldehyde solution and 0.1 ml HCl, keep for 10 min and perform the titration.

1.2.4 Observations

Weight of sample taken for extraction with HPO_3 = W = ----- g

Volume of the sample made up with HPO_3 solution = 100 = ----- ml

Volume of sample extract taken for dye titration = V_1 = ----- ml

Volume of dye required (titre) = V_2 = ----- ml

1.2.5 Calculations

Ascorbic acid in V_1 ml of the sample extract = dye factor x V_2 = mg

$$\text{Therefore, ascorbic acid in 100 ml of the extract} = \frac{\text{Dye factor} \times V_2 \times 100}{V_1} = \text{mg}$$

Since W g sample was made up to 100 ml, ascorbic acid content of the sample (mg per 100 g)

$$= \frac{\text{Dye factor} \times V_2 \times 100 \times 100}{V_1 \times W} = \frac{\text{Dye factor} \times V_2 \times 10{,}000}{V_1 \times W}$$

1.2.6 Results

Ascorbic acid content of the sample = mg per 100 g.

1.3 EXPERIMENT 1b: XYLENE EXTRACTION METHOD

1.3.1 Principle

This method is based on measurement of the extent to which a 2,6-dichlorophenol indophenol solution is decolourised by ascorbic acid in sample extracts and in standard ascorbic acid solutions. The excess dye is taken up in xylene and colour measured in a colorimeter at 520 nm. This method is particularly suitable for stored products in which considerable interfering substances are present.

1.3.2 Requirements

Colorimeter with sufficient number of sample tubes

Analytical balance, 0.1 mg sensitivity

Volumetric flask, 100 ml, and 1000 ml

Pipette, 10 ml

Conical flasks, 50 ml glass stoppered

Funnel

Whatman No.1 filter circles

Reagents

i) Acetate buffer- pH 4: Mix 500 ml of 50% sodium acetate ($CH_3COONa.3H_2O$) with 500 ml of glacial acetic acid.

ii) Dye: Dissolve 125 mg of 2,6-dichlorophenol indophenol (sodium salt) in warm distilled water, cool , make up to 100 ml in a volumetric flask and filter (stock solution). Dilute 18 ml to 100 ml with water. 1 ml of this solution should be equal to 0.1 mg of ascorbic acid. The stock solution of the dye may be stored in a refrigerator for a week.

iii) Meta phosphoric acid solution (3%): Dissolve 15 g of sticks or pellets of HPO_3 in distilled water and dilute to 500 ml.

iv) Standard ascorbic acid solution: Weigh exactly 100 mg of ascorbic acid and make up to 100 ml with 3% HPO_3 solution. Dilute 10 ml to 100 ml (1 ml = 0.1 mg ascorbic acid).

v) Xylene.

vi) Formaldehyde 40%.

vii) Anhydrous sodium sulphate.

1.3.3 Procedure

Sample extraction procedure followed for the titration method may be followed for this method also.

Standard Curve

Pipette out 0.0, 0.50, 0.75, 1.0, 1.5 and 2.0 ml of the standard ascorbic acid solution into 50 ml stoppered conical flasks. Make up the total volume in each flask to 2 ml with 3% HPO_3 solution. Add 1 ml water, 2 ml acetate buffer, 3 ml dye solution and 15 ml xylene in rapid succession. Stopper the conical flasks and shake vigorously for 10 sec to extract the excess dye into the xylene. Allow the layers to separate. With a pipette completely draw out the water layer below the xylene layer and discard. Add a small quantity (0.5-1 g) of anhydrous Na_2SO_4 to the xylene layer to remove traces of moisture. Transfer the xylene extracts to the colorimeter tubes and measure the absorbance at 520 nm. Set the instrument to 100% transmittance using xylene as blank. Plot the absorbance values (A) against ascorbic acid (mg) on a graph paper to get the standard curve. You will see that as the concentration of ascorbic acid in the reaction mixture increases, the absorbance value decreases.

Vol. of ascorbic acid (ml)	Ascorbic acid (mg)	Absorbance (A)
0.0	0.00	
0.5	0.05	
0.75	0.075	
1.0	0.10	
1.5	0.15	
2.0	0.20	

Sample

Take 2 ml sample extract in a stoppered conical flask, add 2 ml of buffer, 1 ml of 40% formaldehyde and mix. Allow to stand for 10 min. Then add 3 ml dye solution, stopper and shake for 10-15 sec. Follow the remaining steps as done in the case of standard curve preparation. From the standard curve note the ascorbic acid content (mg) in the 2 ml sample extract taken for the estimation.

1.3.4 Observations

Absorbance of the xylene extract = A_1

Corresponding ascorbic acid content from the standard curve = W_1 = ---- mg

Weight of the sample taken for extraction = W_2 = ----- g

Volume of the sample made up for ascorbic acid extraction = 100 = ---- ml

1.3.5 Calculations

From the data, W_1 mg of ascorbic acid is present in 2 ml of the sample extract.

As W g of the sample was made up to 100 ml for extraction of ascorbic acid, the ascorbic acid content of the sample (mg per 100 g)

$$= \frac{W_1 \times 100 \times 100}{2 \times W_2} = \frac{W_1 \times 5000}{W_2}$$

1.3.6 Results

Ascorbic acid of the sample = mg per 100 g.

1.4 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

The colorimeter and the sample tubes should be handled with care.

EXPERIMENT 2 DETERMINATION OF SODIUM CHLORIDE

Structure

2.1 INTRODUCTION

Salt (sodium chloride) is an important ingredient in several food products like pickles, chutneys, and sauces. Brine (dilute salt solution) is the common covering liquid for most of the low acid canned products like vegetables. In products like "pickle in brine", the minimum salt content has been specified.

The approximate salt content in brine solutions can be measured using a salinometer (hygrometer). However, for more accurate determination of sodium chloride, silver nitrate titration method is mostly followed.

Objectives

After studying and performing this experiment, you should be able to

- determine the salt content of food products.

2.2 EXPERIMENT

2.2.1 Principle

When a sample extract containing sodium chloride to which a few drops of potassium chromate solution is added, is titrated with standard silver nitrate solution, silver nitrate precipitates chloride as silver chloride. Immediately on completion of the precipitation reaction, the excess of silver nitrate reacts with potassium chromate forming reddish brown silver chromate, which is the end point. The quantity of silver nitrate used for the precipitation is the measure of the sodium chloride content of the sample.

$$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$$

2.2.2 Requirements

Glassware and other items

Chemical balance	
Burette, 25 ml	–1
Conical flask, 250 ml	–2

Measuring cylinder

Whatman No.1 filter paper circles,

Funnel, 4 inch –2

Reagents

5% Potassium chromate solution (indicator)

0.1N Silver nitrate solution

Calcium carbonate powder

2.2.3 Procedure

Weigh 25 to 50 g of homogenized sample depending on the salt content. Dilute with distilled water and neutralize with 0.1N sodium hydroxide solution using phenolphthalein as indicator. Transfer to a 250 ml volumetric flask, make up to volume, shake and filter. Titrate an aliquot with 0.1 N silver nitrate solution adding about 1ml of 5% aqueous potassium chromate solution as indicator. Note the volume of silver nitrate solution required to produce the reddish brown end point colour. Carry out a blank titration with distilled water of same volume as the sample aliquot.

2.2.4 Observations

Weight of the sample	= W = ------- g
Volume made up	= V = ------- ml
Volume taken for titration	= V_1= ------- ml
Volume of silver nitrate solution required for sample	= V_2 = ------ ml
Volume of silver nitrate required for blank titration	= V_3= ------- ml
Normality of the $AgNO_3$ solution	= N

2.2.5 Calculations

1000 ml 1 N $AgNO_3$ solution = 1 g mole of sodium chloride = 58.45 g.

Therefore, % NaCl in the sample =

$$\frac{58.45\,(\text{sample titre} - \text{blank titre})\,N \times \text{volume made up} \times 100}{1000 \times \text{aliquot volume taken for titration} \times \text{weight of sample}}$$

i.e. % sodium chloride in the sample = $\dfrac{58.45\,(V_2 - V_3)\,N \times V}{10 \times V_1 \times W}$

2.2.6 Results

Salt content in the sample = Percent.

2.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

Handle silver nitrate and its solution with care. They can leave permanent stain on the skin and cloth.

EXPERIMENT 3 DETERMINATION OF TOTAL CAROTENOIDS AND BETA-CAROTENE BY COLORIMETRIC METHOD

Structure

3.1 INTRODUCTION

Carotenoids are a group of yellow, orange and orange-red fat-soluble pigments widely distributed in nature. The carotenoids are of great nutritional importance as some of them are converted into vitamin A. Several fruits and vegetables especially the leafy vegetables are good sources for carotenoids. Therefore, estimation of their concentration in fresh and processed foods is important.

Extracting into solvents like petroleum ether and measuring the colour at 452 nm in a colorimeter most commonly estimate total carotenoids in food materials. Beta-carotene is chromatographically separated from total carotenoids on a suitable adsorbent and colorimetrically estimated.

Objectives

After studying and performing this experiment, you should be able to

- extract carotenoid pigments from food materials;
- separate beta-carotene from the total carotenoids chromatographically; and
- estimate them colorimetrically.

3.2 EXPERIMENT: TOTAL CAROTENOIDS AND BETA-CAROTENE ESTIMATION

3.2.1 Principle

Carotenoid pigments (carotenes, xanthophylls and santhophyllesters) being fat-soluble substances, can be extracted into water immiscible solvents like petroleum ether. The absorbance of the extract is measured in a colorimeter or spectrophotometer, and the carotenoids concentration is calculated using a standard curve. Beta-carotene can be separated from total carotenoids extract chromatographically on a magnesium oxide- supercel column and separately estimated.

3.2.2 Requirements

Apparatus

Colorimeter or specrophotometer

Chromatographic column, 150 x 19 mm (ID) glass tubes with constriction at one end to attach 3 mm glass tubing. The column should be fixed to a rubber cork, which should fix to a 100 ml Buchner flask.

Plunger for the preparation of the adsorption column.

Buchner flask, 100 ml	–2
Suction pump	
Analytical balance, 0.1 mg sensitivity	
Pestle and mortar	
Volumetric flask, 100 ml	–6
------ do ----- , 250 ml	–1
------- do ---------, 25 ml	–2
Pipettes, 5 and 10 ml	
Conical flask, 250 ml	–2
Funnels, 3 inch	–2
Separating funnel, 250 ml	–2

Reagents

Petroleun ether (b.p. 65-70^{0}C)

Acetone

Chloroform

Anhydrous sodium sulphate

Adsorbent: Mix one part of magnesium oxide (MgO) with three parts of supercel.

3% acetone in petroleum ether

Sea sand, purified

Surgical cotton

3.2.3 Procedure

Standard Curve of β-carotene

Weigh accurately 25 mg of β-carotene and dissolve in 2.5 ml chloroform and make up to 250 ml with petroleum ether (1 ml = 0.1 mg or 100 μg). Dilute 10 ml of this solution to 100 ml with petroleum ether in a volumetric flask (1 ml = 10 μg). Pipette 5, 10, 15, 20, 25 and 30 ml of this solution to separate 100 ml volumetric flasks, each containing 3 ml acetone and dilute to mark with petroleum ether. The concentration of β -carotene in these solutions will be 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 μg per ml. Measure the absorbance of the solutions at

452 nm using 3% acetone in petroleum ether as blank. Draw a graph by plotting absorbance against concentration. Record the data as follows.

β-carotene (μg/ ml)	**Absorbance(A)**
0.5	
1.0	
1.5	
2.0	
2.5	
3.0	

Sample Extraction

Weigh a well-blended sample (5 to 25 g) containing 10 to 500 μg total carotenoids. Grind in a pestle and mortar with acetone adding small quantity of pure sand. Filter through cotton into a conical flask. Continue extraction and filtration till the residue is colourless. Transfer the combined filtrate to a separating funnel. Add 10 to 15 ml petroleum ether followed by distilled water to transfer the pigments to the petroleum ether phase. Drain out the aqueous phase and filter the petroleum ether extract through anhydrous sodium sulphate. Make up the petroleum volume of the ether extract to 25 ml in a volumetric flask with petroleum ether. Measure the absorption of the solution at 452 nm. Calculate the total carotenoids contents using the standard curve. The results are expressed in terms of β-carotene as μg per 100 g of the material.

Chromatographic Separation of β-carotene

Preparation of column: Attach the column to a Buchner flask, apply vacuum and pack the glass column tightly with the adsorbent to a height of about 10 cm. alternatively, press the adsorbent, 2-3 times with a plunger to ensure a tight column. Add anhydrous Na_2SO_4 to the top of the column to about 1 cm height.

Sample adsorption and elution: Wash the column with 25 to 50 ml petroleum ether with suction. When the petroleum layer has almost reached the Na_2SO_4 surface, disconnect suction pump and attach the column tube to another clean and dry Buchner flask. Pipette out 5 to10 ml of the sample extract into the column and apply suction. Wash the column continuously with 3% acetone in petroleum ether (eluent) taking care not to allow the solvent layer to go below the Na_2SO_4 layer. β-carotene moves out of the column prior to all other pigments. When the β-carotene band has flowed out completely, disconnect suction and transfer the contents of the Buchner flask to a volumetric flask and make up to volume with the eluent. Measure the absorbance of the solution at 452 nm using 3% acetone in petroleum ether as blank.

3.2.4 Observations

Weight of sample taken for carotenoids extraction = W = ----- g

Volume of the petroleum ether extract of the sample = V = ----- ml

Absorbance of the solution = A

Concentration of carotenoids in the solution (from std. curve) = C = μg/ml

Volume of the petroleum ether extract taken for

Chromatography = V_1 = ----- ml

Volume of the β- carotene band made up to = V_2 = ----- ml

Absorbance of the β-carotene extract = A_1

Concentration of β-carotene in the solution (from std. curve) = C_1 = -- μg/ml

3.2.5 Calculations

Total Carotenoids

Concentration total carotenoids in the petroleum ether extract = C = μg/ ml

Therefore, total carotenoids content in V ml of the petroleum ether extract

$$= C \times V = \mu g$$

C × V μg carotenoids are present in W g of the sample

$$\text{Therefore, total carotenoids content in the sample} = \frac{C \times V \times 100}{W} = \mu g \text{ per } 100 \text{ g}$$

β-carotene

Concentration of β-carotene in the β-carotene eluate = C_1 = μg/ml

Therefore, β-carotene content in V_2 ml of the eluate = $C_1 \times V_2$ = μg

$C_1 \times V_2$ μg of β-carotene is present in V_1 ml of the extract taken for chromatography.

$$\text{Therefore, } \beta\text{-carotene content in the sample} = \frac{C_1 \times V_2 \times V \times 100}{V_1 \times W} = \mu g \text{ per } 100 \text{ g}$$

3.2.6 Results

Total carotenoids content of the sample = μg per 100 g.

β-carotene content of the sample = μg per 100 g.

3.3 PRECAUTIONS

β-carotene is unstable to light and susceptible to air-oxidation. Therefore, the sample extracts should be prevented from oxidation and light.

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

Never handle petroleum ether near a flame. The solvents should be handled only in a well-ventilated room or inside a hood with exhaust. Avoid inhaling the solvents directly.

EXPERIMENT 4 DETERMINATION OF SULPHUR DIOXIDE

Structure

4.1 INTRODUCTION

Sulphur dioxide and sulphites are versatile food preservatives having several beneficial functions. Sulphur oxide added to food products as preservative may exist as undissociated sulphurous acid, as free bisulphite ion, as free sulphite ion, and/or as combined SO_2 in the form of hydroxy sulphonates. However, they can cause harmful effects if consumed in higher quantities. Therefore, like for all other preservatives, maximum permissible limits of sulphites in foods have been laid down. Besides, sulphites are not permitted in all foods.

There are two methods used for the estimation of sulphites in foods. Both of them make use of the reducing property of sulphur dioxide. In one method, iodine is used to oxidize sulphur dioxide (sulphurous acid to sulphuric acid in aqueous solution) and in the other method, hydrogen peroxide is used for the oxidation reaction after liberating sulphur dioxide from the product. The latter method is more reliable and hence followed widely.

Objectives

After studying and performing this experiment, you should be able to

- estimate the sulphur dioxide content of food products by the distillation method.

4.2 EXPERIMENT

4.2.1 Principle

This method measures total sulphur dioxide in food products. Sulphites present in the product are liberated as sulphur dioxide by boiling with hydrochloric acid. The liberated sulphur dioxide is absorbed in hydrogen peroxide solution, which oxidizes it to sulphuric acid. Sulfite content is directly related to generated suphuric acid, which is determined by titration with standard sodium hydroxide solution.

The reactions involved are:

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$H_2O_2 + SO_2 \rightarrow H_2SO_4$$

4.2.2 Requirements

Apparatus

a) All glass distillation apparatus for determination of sulphur dioxide shown in the diagram below.

Diagram: SR p 307

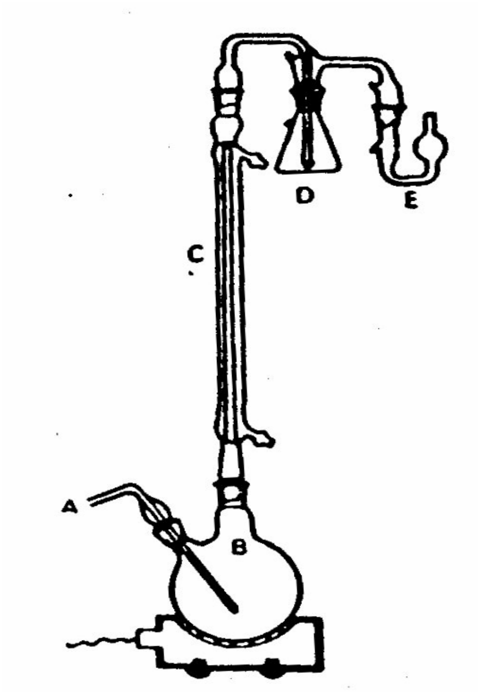


Figure 4.1: All glass distillation apparatus for determination of sulphur dioxide. A) glass inlet tube, B) 500ml round-bottomed flask, C) condenser, D) 250 ml conical flask, E) trap

b) Burette: - 10 ml

Reagents

a) **Aqueous hydrochloric acid:** -4M. For each analysis, prepare 90 ml solution by adding 30 ml HCl to 60 ml deionized water.

b) **Methyl red indicator: -**Dissolve 250 mg methyl red in 100 ml ethanol.

c) **0.05 N NaOH solution.**

d) **3% Hydrogen peroxide solution: -**. For each analysis, dilute 3 ml reagent grade 30% H_2O_2 to 30 ml with distilled water. Just prior to use, add 3 drops methyl red indicator and titrate with 0.01N NaOH to yellow end point.

e) **Nitrogen gas: -**High purity, used with regulator to maintain flow of 200 ml/min.

4.2.3 Procedure

Circulate cold water through condenser of the distillation apparatus. Add from a graduated cylinder, 20ml of 3% hydrogen peroxide solution to the conical flask (D) and 5 ml to the trap (E). Assemble the apparatus and connect condenser. Weigh 50g of blended sample into the round-bottomed flask (B) through gas inlet tube joint, using 300ml of water. Replace the inlet tube immediately, making sure all connections are well greased and tight. Remove the inlet tube, and slowly add 20ml of 4N HCl. Ensure that bubbles of nitrogen gas enter the receiving flask through the gas inlet tube. If not, check joints for leaks. Adjust nitrogen to give a flow of 15 to 20 bubbles per minute through the tube. Heat the content of the flask to boil and adjust the heater to give a slow boil. Continue boiling for 30 mins. Stop heating and disconnect the assembly and remove the conical flask and the trap containing hydrogen peroxide. Transfer the hydrogen peroxide solution from the trap into the conical flask and rinse the trap with water and transfer the rinsing to the flask.

Determination

Add 3 drops of the indicator. Immediately titrate contents of conical flask (D) with 0.05N NaOH to yellow end point that persists for about 20 seconds. Compute sulfite content, expressed in mg SO_2/Kg food (ppm).

4.2.4 Observations

Weight of the sample	= W = ----- g
Normality of the NaOH solution	= N
Volume of NaOH (titre)	= V = ----- ml

4.2.5 Calculations

1 ml of 0.05N NaOH = 1.6 mg of SO_2

$$\text{Therefore, V ml of N normal NaOH} = \frac{(V \times N \times 1.6)}{0.05} = (V \times N \times 32) \text{ --- mg } SO_2$$

Since (V x N x 32) mg SO_2 is present in W g of the sample

$$\text{Therefore, } SO_2 \text{ (mg) in 1 Kg of the sample (ppm)} = \frac{(V \times N \times 32)}{W} \times 1000$$

4.2.6 Results

SO_2 in the sample = ppm = mg per kilogram.

4.3 PRECAUTIONS

The general precautions mentioned in the course ‘Introduction’ and those indicated in the experiments should be followed meticulously.

Handle the all glass distillation apparatus very carefully. It may easily break because the joints are rigid.

EXPERIMENT 5 ESTIMATION OF BENZOIC ACID

Structure

5.1 INTRODUCTION

Benzoic acid is the second most common preservative added to fruit and vegetable products. Being insoluble in water, it is added as the soluble sodium benzoate. The method commonly followed for the estimation of benzoic acid involves conversion of the salt into benzoic acid by acidification, extraction into an organic solvent and titrating against alkali.

Objectives

After studying and performing this experiment, you should be able to

- determine the benzoic acid content of foods by the extraction and alkali titration method.

5.2 EXPERIMENT

5.2.1 Principle

In sodium chloride solution of the sample, the benzoic acid present is converted into water-soluble sodium benzoate by the addition of NaOH. When the sodium benzoate solution is acidified with excess HCl, it is converted into benzoic acid. The water insoluble benzoic acid is extracted with chloroform. The chloroform is removed by evaporation and the residue containing benzoic acid, which appears as leafy crystals, is dissolved in neutral alcohol and titrated against standard NaOH to phenolphthalein end point.

5.2.2 Requirements

Equipment and Apparatus

Separating funnel, 500 ml	–1
Beaker, 250 ml	–2
Volumetric flask, 250 ml & 500 ml	–1 each
Burette, 50 ml	–1

Pipette, 25 ml –1

Measuring cylinders, 50 ml and 10 ml –1 each

Water-bath –1

Chemical balance –1

Desiccator –1

Whatman No. 1 or No. 4 filter paper circles

Chemicals and Reagents

Diethyl ether,

Hydrochloric acid – (1+ 3)

Anhydrous sodium sulphate

Ethyl alcohol

Phenolphthalein indicator – 0.1% in alcohol

Sodium hydroxide solution – 0.05 N

Ferric chloride solution – 0.5%

Sodium chloride – saturated solution

Sodium hydroxide – 10 % solution

Chloroform

Sodium chloride – powder

5.2.3 Procedure

a) Detection

Transfer homogenized sample into a separating funnel. Acidify with 1+3 HCl. Extract with solvent ether. Collect ether in a dry conical flask. Evaporate ether to near dryness and completely evaporate under a current of dry air. To the white leafy crystals of benzoic acid add few drops of 0.5% neutral $FeCl_3$ solution. A salmon coloured precipitate confirms presence of benzoic acid.

b) Determination

Take 50-75 g of the homogenized sample in a 500ml beaker. Add 200ml saturated solution of NaCl and 50g powder NaCl and stir well. Make the solution alkaline to litmus paper with 10% NaOH. Quantitatively transfer the solution to 250ml volumetric flask and make up to volume. Shake well. Let stand 2-3 hr. with frequent shaking. Filter through whatman No. 4 filter paper. Pipette 50ml filtrate into a separating funnel. Neutralize to litmus paper with HCl (1+3). Add 5ml in excess of the acid. Extract the solution thrice with 70, 50, 30 ml portions of chloroform. Shake funnel using rotary motion with each extraction. If emulsion forms, break it by (a) Stirring $CHCl_3$ layer with a glass rod, or (b) draw $CHCl_3$ layer into a second separating funnel and give one or two sharp shake. Pool clear $CHCl_3$ extracts and transfer to separating funnel. Wash the chloroform extract with

5ml water. Draw the $CHCl_3$ layer into a 250ml conical flask. (the $CHCl_3$ extract may be passed through a bed of cotton and anhydrous Na_2SO_4 to remove traces of moisture). Evaporate $CHCl_3$ to near dryness on water bath. Dry completely under a current of dry air. Keep the flask overnight in a H_2SO_4 desiccator. Remove and add 25ml neutral alcohol. Add 6-8 ml of water and one drop of phenolphthalein indicator and titrate against 0.05N NaOH.

5.2.4 Observations

Weight of the sample	= W = ---- g
Volume made up	= V = ---- ml
Volume taken for extracting with chloroform	= V_1 = ---- ml
Titre value	= V_2 = ---- ml
Normality of the NaOH	= N

5.2.5 Calculations

1000 ml 1N NaOH = 1 g equivalent of benzoic acid = 122 g benzoic acid

or 1 ml 1 N NaOH = 122 mg benzoic acid

Therefore ppm (mg per Kg) of benzoic acid in the product =

$$\frac{\text{Vol. of alkali} \times \text{Normality of NaOH} \times \text{Vol. made up}}{\text{Vol. Taken for } CHCl_3 \text{ extraction} \times \text{Weight of sample}} \times 122 \times 1000$$

$$= \frac{V_2 \times N \times V \times 122 \times 1000}{V_1 \times W} = \text{ppm}$$

5.2.6 Results

The result is expressed as benzoic acid in ppm.

5.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

Never handle ether near a flame. The solvents should be handled only in a well-ventilated room or inside a hood with exhaust. Avoid inhaling the solvents directly.

EXPERIMENT 6 DETERMINATION OF HARDNESS OF WATER

Structure

6.1 INTRODUCTION

Hardness of water is almost entirely due to the presence of calcium and magnesium salts. It is expressed as ppm (mg/ litre). Hardness values for water meant for different purposes have been specified.

The most common method for the determination of hardness of water is by the ethylenediamine tetra-acetic acid (EDTA) titration.

Objectives

After studying and performing this experiment, you should be able to

- determine the hardness of water.

6.2 EXPERIMENT: HARDNESS OF WATER BY EDTA METHOD

6.2.1 Principle

This method is based on the principle that when EDTA is added to a solution containing certain metal cations like calcium and magnesium, it complexes with them and make them unavailable for some reactions. One such reaction is the formation of wine-red colour between the cations and Chrome black T at a pH of 10. Therefore, for the determination of hardness of water, Chrome black T is added to the water at pH 10 ± 0.1 and titrated with EDTA solution till the disappearance of wine-red colour and formation of blue colour, which is the end point.

6.2.2 Requirements

Apparatus

Analytical balance

Hot air oven

Desiccator

Volumetric flasks, 500 ml and 1000 ml

Conical flask, 250 ml and 500 ml

White porcelain dish, 250 ml

Glass rods

Reagents

i) Borate buffer: Dissolve 20 g borax ($Na_2B_4O_7.10\ H_2O$) in about 400 ml distilled water. Dissolve 5 g sodium hydroxide and 2.5 g sodium sulphide (Na_2S) in 50 ml water, cool, mix with borax solution and dilute to 500 ml with distilled water.

ii) Indicator: Mix together 0.5 g of Eriochrome black T and 100 g sodium chloride and powder in a pestle and mortar.

iii) Methyl red indicator.

iv) 3N ammonium hydroxide solution.

v) Standard calcium solution: Dry calcium carbonate ($CaCO_3$) in an oven at 105^{o}C over night and cool in a desiccator. Weigh exactly 1 g into a 500 ml conical flask. Add dilute (1+1) HCl drop by drop until all the $CaCO_3$ has dissolved. Add 200 ml distilled water and boil for a few minutes to expel carbon dioxide. Cool, add a few drops of methyl red indicator and adjust to the intermediate orange colour by adding 3N ammonium hydroxide. Transfer to a 1 litre volumetric flask and make up to volume with distilled water (1 ml = 1 mg $CaCO_3$).

vi) Standard EDTA solution: Dissolve 4.0 g of disodium salt of EDTA in 800 ml of distilled water. Standardize against standard calcium solution. Adjust the dilution of the EDTA solution such that 1 ml = 1 mg $CaCO_3$. Store in a corning glass or plastic bottle to prevent extraction of salts from ordinary glass.

6.2.3 Procedure

Take 25 ml of the water sample in a porcelain dish and add 25 ml distilled water followed by 1-2 ml of the buffer. Add a small quantity of the Eriochrome indicator and stir with a glass rod to dissolve. If the water is hard, a red colour will be formed. Titrate slowly with the EDTA solution, stirring continuously until the red tinge disappears and a permanent blue colour is produced. If the water sample has low hardness, more volume of water may be taken for titration by adding proportionate volume of the buffer. The duration of titration should not exceed 5 min measured from the time of addition of buffer.

6.2.4 Observations

Volume of water sample taken for titration = V = ----- ml

Volume of EDTA solution required (titre) = V_1 = ----- ml

6.2.5 Calculations

Since 1 ml of the EDTA solution is equal to 1 mg $CaCO_3$, V_1 ml EDTA solution = V_1 mg $CaCO_3$.

As V_1 mg $CaCO_3$ is present in V ml of the water sample, the hardness of the water.

$$= \frac{V_1 \times 1000}{V} = \text{ppm } CaCO_3 \text{ or mg } CaCO_3 \text{ per litre.}$$

6.2.6 Results

Hardness of the water sample = ppm $CaCO_3$ or mg $CaCO_3$ per litre.

6.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

EXPERIMENT 7 ESTIMATION OF RESIDUAL CHLORINE IN WATER

Structure

7.1 INTRODUCTION

Water is routinely chlorinated to make it microbiologically safe. When chlorine is added to water other than distilled water, initially a small amount reacts with impurities in the water and does not show as residual chlorine. This is called the chlorine demand of the water, which has no germicidal effect. Chlorine added subsequently remains as the residual chlorine (free available and combined available chlorine), which is important for disinfection. The residual chlorine levels of water used for different purposes have been specified.

The most common method for routine estimation of residual chlorine is the iodometric method, which you will learn in this practical.

Objectives

After studying and performing this experiment, you should be able to

- determine the residual chlorine content in water; and
- follow the necessary sampling procedures.

7.2 EXPERIMENT: RESIDUAL CHLORINE BY IODOMETRIC METHOD

7.2.1 Principle

Chlorine liberates free iodine from potassium iodide solution in acidic pH quantitatively. The liberated iodine is determined by titration with standard sodium thiosulphate solution. As chlorine in aqueous solution is not stable, the determination of chlorine must be performed immediately after sampling. Care should be taken to avoid excessive exposure of the water sample to sunlight and agitation.

7.2.2 Requirements

Apparatus / glassware

Analytical balance

Burette, 25 ml

Volumetric flask, 100 and 250 ml

Conical flask, 250 ml

Measuring cylinder, 500 ml

White porcelain dish, 500 ml

Beaker, 250 ml

Reagents

i) Acetic acid, glacial.

ii) Potassium iodide crystals.

iii) Starch indicator.

iv) N sodium thiosulphate solution: Dissolve 24.8192 g of sodium thiosulphate ($Na_2S_2O_5$. 5 H_2O) in 200 ml water and transfer to a 1 litre volumetric flask and make up to volume. Standardize the solution with potassium dichromate. Weigh 0.20 to 0.23 g $K_2Cr_2O_7$ and transfer to a 250 ml beaker using about 150 ml water. Add 2 g potassium iodide and mix. Add 20 ml of 1 N HCl , swirl and allow to stand for 10 min. Titrate with the thisuphate solution adding 1 ml of 1% starch solution towards the end of titration and complete titration where the solution changes from blue green to light green.

$$\text{Normality of sodium thiosulphate solution} = \frac{\text{Wt of } K_2Cr_2O_7 \text{ (g)} \times 1000}{\text{Vol. of } Na_2S_2O_3 \text{ (ml)} \times 49.037}$$

Prepare 0.01 N working standard by diluting the 0.1 N thosuphate solution.

7.2.3 Procedure

Take a suitable volume of the water sample into a porcelain dish or beaker. For water containing 1 mg / litre or less chlorine take 1000 ml and for 1 to 10 mg / litre take 500 ml. The titre value of 0.01 N thiosulphate should not be more than 20 ml. Add 5 ml glacial acetic acid followed by 1 g potassium iodide, stir and titrate with 0.01 N thiosulphate solution until the yellow colour of the liberated iodine is almost disappears. Add 1 ml starch solution and titrate until the blue colour is discharged. Do not carry out the titration in direct sunlight. Blank titration can be carried out by taking equal volume of distilled water.

7.2.4 Observations

Volume of water taken for titration = V = ----- ml

Volume of thiosulphate solution required (titre) = V_1 = ----- ml

Normality of sodium thiosulphate solution = 0.01 N

7.2.5 Calculations

1000 ml 1N sodium thiosuphate = 35.46 g chlorine (i.e.1 g mole of chlorine)

or 1 ml 1N sodium thiosulphate = 35.46 mg chlorine

or V_1 ml of 0.1 N sodium thiosulphate = V_1 x 0.01 x 35.46 mg chlorine

Therefore, residual chlorine content of the water (mg per litre)

$$= \frac{V_1 \times 0.01 \times 35.46 \times 1000}{V}$$

$$= \frac{V_1 \times 354.6}{V}$$

7.2.6 Results

Residual chlorine content of the water sample = mg per litre or ppm.

7.3 PRECAUTIONS

The general precautions mentioned in the course ‘Introduction’ and those indicated in the experiments should be followed meticulously.

EXPERIMENT 8 DETERMINATION OF TOTAL SOLUBLE SOLIDS (°BRIX)

Structure

8.1 INTRODUCTION

Total soluble solids may be determined by means of Refractometer. Brix is a measure of total soluble solids (TSS) in the case of pure sucrose solutions. Generally fruit juices contain more sugar than other soluble constituents, and hence, Brix provides useful guide of TSS or sugar content.

The concentration of sugar solutions can be determined conveniently for routine purposes using a refractometer. There are two types of refractometers viz. hand refractometers and Abbe's refractometers, the latter being tabletop instrument, which can measure both ^{o}Brix (TSS) of sugar solutions and also there is provision for maintaining constant temperature.

It should be noted that the refractometers are calibrated for sugar solutions and hence if the medium contains other soluble solutes in substantial quantities, there will be slight error.

Objectives

After studying and performing this experiment, you should be able to

- determine the °Brix of sugar solutions and TSS of food products.

8.2 EXPERIMENT

8.2.1 Principle

Refractometer measures total soluble solids (TSS) concentration based on the principle of refraction of light. When a ray of light travels obliquely from one medium to another, it is bent or refracted. The refraction occurs because light travels at slightly different velocities in different media, the extent being proportional to the density of the solution or the soluble solids concentration. The refractive index of a medium is defined as the ratio of the sine of the angle of incidence to the sine of the angle of refraction when a ray of monochromatic light is refracted from a vacuum (or, to a very close approximation, from air) into the medium. In a Brix refractometer, the refractive index is calibrated into ^{o}Brix readings. As refractive index is dependent on the density of the solution, the measurements have to be made at a specific temperature (20°C) or suitable corrections have to be applied.

8.2.2 Requirements

Equipments

Hand Refractometer or Abbe's Refractometer

Thermostatically controlled water bath.

8.2.3 Procedure

Place few drops of the sample in between the prisms of hand refractometer and note the reading at the demarcation line. Apply temperature correction for readings taken at temperatures other than 20°C using the following table.

In the case of Abbe's refractometer, circulate 20°C water in the chamber enclosing the prism from a thermostatically controlled water bath. Place a few drops of the sample in between the prisms and allow the temperature to equilibrate and note the Brix reading, which gives per cent of sucrose sugar or TSS.

If sample is thick, squeeze it through cotton and place the drop in between the prisms.

8.2.4 Results

The readings are expressed as total soluble solids (TSS) = %.

Temperature corrections for readings of per cent sucrose in sugar solution by either Abbe or Immersion refractometer at temperatures other than 20°C.

Table 8.1: International temperature correction table, 1936

Temp (°C)	Percent Sucrose										
	0	5	10	15	20	25	30	40	50	60	70
Subtract from Per Cent Sucrose											
10	0.50	0.54	0.58	0.61	0.64	0.66	0.68	0.72	0.74	0.76	0.7
11	0.46	0.49	0.53	0.55	0.58	0.60	0.62	0.65	0.67	0.69	0.7
12	0.42	0.45	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.61	0.6
13	0.37	0.40	0.42	0.44	0.46	0.48	0.49	0.51	0.53	0.54	0.5
14	0.33	0.35	0.37	0.39	0.40	0.41	0.42	0.44	0.45	0.46	0.4
15	0.27	0.29	0.31	0.33	0.34	0.34	0.35	0.37	0.38	0.39	0.40
16	0.22	0.24	0.25	0.26	0.27	0.28	0.28	0.30	0.30	0.31	0.32
17	0.17	0.18	0.19	0.20	0.21	0.21	0.21	0.22	0.23	0.23	0.24
18	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.16	0.16
19	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08

Add to Per Cent Sucrose										
21	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08
22	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.16
23	0.19	0.20	0.21	0.22	0.22	0.23	0.23	0.23	0.24	0.24	0.24
24	0.26	0.27	0.28	0.29	0.30	0.30	0.31	0.31	0.31	0.32	0.32
25	0.33	0.35	0.36	0.37	0.38	0.38	0.39	0.40	0.40	0.40	0.40
26	0.40	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.48	0.48	0.48
27	0.48	0.50	0.52	0.53	0.54	0.55	0.55	0.56	0.56	0.56	0.56
28	0.56	0.57	0.60	0.61	0.62	0.63	0.63	0.64	0.64	0.64	0.64
29	0.64	0.66	0.68	0.69	0.71	0.72	0.72	0.73	0.73	0.73	0.73
30	0.72	0.74	0.77	0.78	0.79	0.80	0.80	0.81	0.81	0.81	0.81

8.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

EXPERIMENT 9 CONTAMINANTS: TIN CONTENT IN CANNED FOODS

Structure

9.1 INTRODUCTION

Food contaminants are substances, which can cause harmful effects in the human system. They generally are pesticide residues, heavy metals, toxins and harmful microorganisms. Therefore, their detection and determination in foods is very important. However, the methods available for the determination of most of the contaminants require very sophisticated instruments and are time consuming. Therefore, most of these analyses are done in specialized laboratories and usually not done in the food processing industries.

One of the few estimations, which can be done easily, is tin content in canned foods. Canned food industry is one of the largest food processing industries. Dissolution of tin (can corrosion) into the canned product during storage is a common problem in canned foods. Excess tin dissolution causes discolouration and flavour change in the products and gives an unattractive appearance to can interior. Excess tin is also harmful to the human system. Therefore, maximum limits for tin content in canned foods have been specified.

Tin content in canned foods is usually determined by iodimetry.

Objectives

After studying and performing this experiment, you should be able to

- carry out ashing of food products for tin estimation; and
- perform the iodimetric estimation of tin.

9.2 EXPERIMENT: TIN ESTIMATION BY IODIMETRY

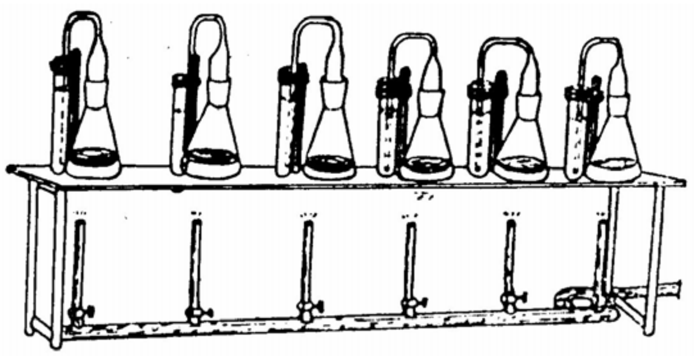
9.2.1 Principle

Canned food sample is acid digested (wet digested) to destroy the organic matter. Tin salts present in the digested sample are reduced with nascent hydrogen to stannous form. Titration of the stannous tin with potassium iodate quantitatively estimates tin.

9.2.2 Requirements

Instruments and Apparatus

Analytical balance	
Blender	
Kjeldahl digestion flask, 300 ml	–2
Pipettes, 10 ml	–2
Burette, 10 ml	–2
Volumetric flasks, 50, 100 ml, 500 ml, 1 lit	–1 each
Conical flask, 150ml with glass jointed (B24) capillary bent tube:	–2
Test tubes, 20 ml	–2
Glass beads	



Set of flasks used for reduction of tin salts

Reagents

i) Conc. HNO_3

ii) Conc. H_2SO_4

iii) Hydrogen peroxide

iv) 3N HCl: Dilute 294.6 ml conc.HCl to 1 litre with distilled water

v) Potassium iodide solution: Dissolve 0.2 g of KIO_3 and 3 g sodium bicarbonate in 100 ml of boiled and cooled water. Transfer to a reagent bottle. Add a few drops of HCl and shake. When effervescence ceases, insert stopper.

vi) Potassium iodate stock solution: Dissolve 5.3505 g KIO_3 in boiled and cooled water and make up the volume to 1 litre. Prepare working standard (0.005N) by diluting 5 ml to 100 ml.

vii) Antimont trichloride ($SbCl_3$) solution: Dissolve 1.5 g $SbCl_3$ in 50 ml HCl and dilute to 100 ml.

viii) Standard tin solution: Dissolve 0.5 g pure tin in 250 ml conc. HCl containing 2 drops of antimony trichloride solution and dilute to 500 ml (1 ml = 1 mg tin).

ix) Aluminium foil, pure.

x) 5% sodium bicarbonate solution.

xi) Starch indicator: 1% starch in 20% sodium chloride solution.

Note: The potassium iodide and iodate reagents should be freshly prepared.

9.2.3 Procedure

Empty the contents of the can immediately to a container after opening to avoid further tin pick up. Blend the product in a blender and digest a suitable quantity of the sample.

Wet digestion: Weigh 50 g sample and transfer to a Kjeldahl digestion flask using distilled water. Add a few glass beads and 10 ml conc. H_2SO_4 and 10 ml or more conc. HNO_3. Heat gently until the liquid darkens. Continue addition of HNO_3 in small proportions (1 to 2 ml) and heating until the solution fails to darken. At this stage, all the organic matter would have been oxidized. Cool and add 10 ml of hydrogen peroxide (30%) drop wise and heat until the digest is colourless. Cool and make up to 50 ml in a volumetric flask with distilled water.

Pipette out 20 ml of the digest into the 150 ml conical flask having glass joint. Add 1 drop of antimony trichloride solution, 30 ml of 3N HCl and about 0.3 g aluminium foil. Connect the flask by mean of B24 joint and a capillary bent tube to a "suck-back" test tube containing sodium bicarbonate solution. Sodium bicarbonate sucked into the conical flask, liberates CO_2 to maintain inert atmosphere.

Heat the flask gently until evolution of gas commences. When the aluminium foil has almost completely dissolved, heat again. Boil till the liquid is colourless. Cool the flask in ice water, disconnect the side tube and add about 4 ml potassium iodide solution along the sides of the flask from a pipette to wash down the digested solution. Add a few drops of starch indicator and titrate rapidly with 0.005 N potassium iodide solution to a blue end point. Run a blank determination with the regents at the same time. The blank titre should not be more than 0.2 ml of 0.005 N potassium iodate.

9.2.4 Observations

Weight of the sample taken: = W = ----- g

Volume of the digest made up to: = V = ----- ml

Volume of the digest taken for tin estimation: V_1 = ----- ml

Volume of potassium iodate required (titre): = V_2 = ----- ml

Blank titre: = V_3 = ----- ml

Normality of potassium iodate solution: = 0.005 N

9.2.5 Calculations

1000 ml 1 N KIO_3 = 59.35 g Sn (tin)

or 1 ml 1 N KIO_3 = 59.35 mg tin

Actual volume of the standard iodate required by the sample = (sample titre – blank titre) = $(V_2 - V_3)$

Therefore, tin content in the canned product (mg / Kg or ppm)

$$= \frac{\text{Actual titre} \times \text{Normality of } KIO_3 \times \text{Total volume of digest} \times 59.35 \times 1000}{\text{Volume of digest taken for tin estimation} \times \text{Weight of sample}}$$

$$= \frac{(V_2 - V_3) \times 0.005 \times V \times 59.35 \times 1000}{V_1 \times W} = \text{mg / Kg}$$

9.2.6 Results

Tin content in the product = ppm or mg per Kg.

9.3 PRECAUTIONS

The general precautions mentioned in the course ‘Introduction’ and those indicated in the experiments should be followed meticulously.

Handle the flask assembly with are to prevent breakage.

EXPERIMENT 10 SENSORY EVALUATION OF FOOD PRODUCTS – HEDONIC RATING TEST

Structure

10.1 INTRODUCTION

Sensory quality of food products is of great importance to both the producer or processor and the consumer. Good quality products attract the consumer by satisfying his aesthetic and gustatory senses. Therefore, it is always the endeavour of the processor to produce the best quality product or produce a product having certain qualities accepted by the consumer in a product already available in the market.

You have already learnt the importance and various aspects of sensory analysis in the theory unit 7.2.4 "Sensory analysis of foods/ beverages". Please brush up before performing this test. There are different sensory test methods to suit specific purposes. One of the frequent requirements of the processor while developing a product is to find out the relative acceptability of his product compared to three or four market sample or to develop a product close to the best in the market. One of the simplest sensory test methods to generate such information is the Hedonic rating test. In this exercise you will learn the method and carry out the test.

Objectives

After studying and performing this experiment, you should be able to

- carry out Hedonic rating test on a set of food products; and
- analyse the data to find out the order of their quality of consumer preference for the samples.

10.2 EXPERIMENT: HEDONIC RATING TEST FOR KETCHUP SAMPLES

10.2.1 Principle

The Hedonic rating test is used to measure the consumer acceptability and preference of food products. The panellist is asked to rate the acceptability of the product on a scale of 9 points, ranging from "like extremely" to "dislike extremely". The data are analysed to find out the average of the panellists ratings from which the order of preference if found out.

10.2.2 Requirements

The primary requirement for any sensory test is the panel of members (panellists). For many sensory tests including the Hedonic rating test, a semi-trained panel is sufficient. The minimum number of panellists required for this test is ten. They should be selected from a larger number of people and should be familiarised (trained) with the quality attributes of the product being tested (or they should be familiarised by proper briefing) and the procedure. They should also have at least average sensitivity to the sensory quality attributes like colour and appearance, flavour and taste etc. Besides, they should be willing to spend the time to do the test.

The other requirements are a well-lighted (white light) room with tables (preferably white tops) and chairs. Assuming that 4 samples (tomato ketchup as in this test) are evaluated and 10 panellists are going to evaluate the products, the following glassware and other items are also required.

White porcelain saucers	:	12 (These are sufficient for serving a set of the four samples to three panellists. The saucers can be cleaned and reused)
Teaspoons	:	12
Glass tumblers for water	:	10
Bread	:	1 loaf
Evaluation cards (Sample shown below)	:	10

Specimen evaluation card

HEDONIC RATING TEST

Name…………………… Date……........

Product: Tomato ketchup

Taste the four samples of tomato ketchup and check how much you like or dislike each one. Use the appropriate scale to show your attitude by checking at the point that describes your feeling about the sample.

Scale	**Ketchup samples**			
	Code No.	**Code No.**	**Code No.**	**Code No.**
Like extremely				

Like very much				
Like moderately				
Like slightly				
Neither like nor dislike				
Dislike slightly				
Dislike moderately				
Dislike very much				
Dislike extremely				
Reason for like/ dislike				

(Signature of panellist)

Three columns are provided to accommodate more than one sample if all of them fall at the same point.

10.2.3 Procedure

In this test, four tomato ketchup samples are tested for the preference. One sample could be the one prepared in a factory and the others are the three market samples. Otherwise, all the four samples could be market samples. The ketchup bottles are first marked with code numbers. It is preferable to have three digit random number codes to avoid bias. Single digit numbers like 1,2,3, 4 are likely to cause bias. For example, some panellists may have a tendency to assume No. 1 is the best and No.4 is the worst and vive versa. Random numbers can be taken from random number tables or generated from a calculator. An example of assigning random numbers to four samples is shown below.

Ketchup sample	Code No.
A	897
B	281
C	951
D	418

In the same way, the sets of four saucers are also numbered and small quantities of the ketchup samples are taken in them. Before starting the evaluation, the panellists are briefed about the test procedure, what to look for in the quality of tomato ketchup, two or more samples may be given the same rating if found so etc. Each product has its own quality attributes. For example, in the case of tomato ketchup, good quality attributes are bright characteristic tomato red colour, thick consistency, does not flow easily when the saucer is tilted, does not show separation of serum around the ketchup sample in the saucer etc.

The set of four saucers containing the samples is given to each panellist along with the evaluation card. Drinking water to rinse mouth in between tasting of two samples to clear the taste of the previous sample is provided. Similarly, cubes of bread are provided for eating for the same purpose. If a panellist requires more samples, the same should be provided. On completion of the evaluation, the evaluation cards are collected and the data are analysed as shown below.

10.2.4 Observations and Calculations

To analyse the results, numerical values are assigned to each point on the scale, 1 is usually given to 'like extremely' and 9 to 'dislike extremely'. The scores received for each sample from all the panellists are averaged and compared. The data are tabulated as shown in the following table. The numerical values given in the table are only examples. You have to enter the actual values.

Panellist	Sample-A	Sample-B	Sample-C	Sample-D
1	3	3	6	5
2	4	3	4	5
3	3	1	4	4
4	2	2	3	4
5	3	1	2	3
6	3	2	7	6
7	2	2	3	5
8	3	2	3	8
9	5	3	7	7
10	3	2	4	6
Total	31	21	43	53
Mean score	3.1	2.1	4.3	5.3

10.2.5 Results

Since the numerical scores are assigned in the reverse order i.e., 1 for the highest quality and 9 for the lowest quality point, lower the score total or score average higher the preference. Therefore, the rating of the quality (preference) of the four tomato ketchup samples is in the following order:

Sample-B > Sample-A > Sample-C > Sample-D

10.3 PRECAUTIONS

The general precautions mentioned in the course 'Introduction' and those indicated in the experiments should be followed meticulously.

UNIT 1 BEING AN ENTREPRENEUR: WHAT DOES IT INVOLVE?

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- differentiate between Wage-employment & Self- employment;
- assess the benefit of self-employment;
- evaluate the risk taking behaviour in goal setting;
- become aware of business opportunities; and
- appreciate the linkage between economy & entrepreneurship.

1.1 INTRODUCTION

"Being an entrepreneur" a Career option. "Self-help is the best help" applies in case one chooses to become an entrepreneur. It is not only running and managing an enterprise but also creating jobs for others. It also means taking challenges by utilizing all available resources. Let us now understand how an entrepreneur goes through this process

1.2 BECOMING AN ENTREPRENEUR

As you grow up you have to think about what you would like to do in order to earn your living. If you look around you will find that different people are doing different activities to earn money to look after their family and to lead a decent life. They are choosing different careers based on their knowledge, and experience. For young persons like you, there are two career alternatives:

a) **wage-employment,** i.e. taking a job and serving the boss for a monthly salary

b) **self-employment**, i.e. to start any economic activity of your own for being self-employed. In self-employment, once the activity grows it can also generate wage-employment for others, then it is called **entrepreneurship.** The person who practises entrepreneurship is called an **entrepreneur.**

An entrepreneur is defined as "person in effective control of commercial undertaking; one who undertakes a business or an enterprise".

The economic activity in self-employment may be a small business, a manufacturing unit or a service-cum-repair unit. Individuals generally choose self-employment for the following reasons:

i) Self-employment provides a solution to the problem of unemployment. Unemployment exists to a large extent in rural and urban areas and among the educated and uneducated in India. Hence, the need to promote self-employment.

ii) One self-employed individual can also offer employment to others. The best scope for self-employment exists in a variety of small business like, retail trade, small stores, repair-cum-servicing units, newspaper stalls, dealership-based business activities, small catering places, franchise-based soft-drink vending, ice-cream and small servicing stations, small manufacturing units, etc.

1.3 NEED FOR ENTREPRENEURSHIP

Let us understand the need for and significance of entrepreneurship.

- **Increases national production**

  More and more entrepreneurs are developed they contribute directly to product and process development which in turn increases national economy. For example, more entrepreneurs in the area of food processing sector would be able to maximize the uses of raw material, and the products in food industries would increase.

- **Balanced area development**

  As more entrepreneurs are developed both in rural and urban sectors, it will decrease the dispersal of the people from rural areas to urban areas. It will also help the rural industries to grow as well as the industrially backward areas in the country.

- **Dispersal of economic power**

  It is a process of empowering people. People can have "power" either through muscle, status or money. Entrepreneurship helps to balance "power" through participation, economic gain and position in the society.

- **Reinvestment of profit for the welfare of the area of profit generation**

  It has been observed that entrepreneurial community or people in a particular area would reinvest their profit for the development of roads, infrastructure as well as for the welfare of the people. Take for example, what contributions have been made by the well-known entrepreneurs like Tata's, Birla's and Reliance.

- **Development is a function of motivation and human resource**

  Any development requires participation of human resources. These people have to be motivated for contributing towards development. Entrepreneurship truly contributes to development through the participation of people who are motivated, energetic and have a concern for growth.

- **Entrepreneurial awareness**

  There is a need for creating mass awareness among the people whether they are students, unemployed youth, artisans, retired personnel, or housewives to be aware about entrepreneurship. More and more entrepreneurs lead to economic development.

1.4 BENEFITS TO THE SELF-EMPLOYED

a) Self-employment offers perhaps the best opportunity for gainful use of one's own capabilities and time.

   It is gainful because it generates income for the self-employed individual. In short, one can earn livelihood based on self-employment.

b) Self-employment develops initiative and ability to plan and manage business activity on the part of the individual.

   Thus, it offers scope for development of the individual.

c) In a self-employment situation one learns many things 'on the job' because one has to take all the decisions and also manage the business.

   One learns and develops through self-employment.

d) In self-employment one can grow and expand one's own business and be innovative.

   One learns to be innovative and growth-oriented. Thus, self-employment develops initiative and ability to plan, decide and manage one's own business. The saying "self-help is the best help" applies here also very well.

1.5 WHO IS AN ENTREPRENEUR?

Once you are self-employed you may like to grow and expand so as to become big to achieve great heights in life, one needs to take initiative and be on one's own. If you look around you will find that all those who have become rich and have earned a big name have become so by starting their own enterprises rather than by seeking jobs. In this way, the educated person does not become a burden on the nation but rather builds the nation by starting a small enterprises, which may be a small industrial enterprise to start with, but over a period of time it becomes a large industry. These are the people who are called entrepreneurs.

i) Becoming an Entrepreneur would mean to own one's tasks\jobs, organize activities, and manage and run an enterprise assuming the risk of a business.

ii) Being an entrepreneur would mean independence and having control over one's own life?

iii) Being an entrepreneur would mean being innovative and reaching towards excellence.

iv) Being an entrepreneur would mean creating job opportunities for others.

v) Being an entrepreneur would also mean sensing economic opportunities.

Entrepreneurs have specific qualities; they have special strengths which they draw upon for their foray into business. If you want to start your own enterprise and make it a success, you will have to play different roles at different times and at different stages of the growth of your enterprise. Let us understand some of the special qualities that an entrepreneur needs to develop.

1.6 SETTING CHALLENGING GOAL – RISK TAKING

Risk-taking is an important aspect of entrepreneurial life. Entrepreneurs are calculated risk-takers. They do not aim at goals that can be very easily accomplished. They like challenges. They also do not aim at tasks that are very difficult to accomplish, as they would enjoy a sense of success attained only after accomplishing a challenging goal. They are moderate risk-takers. Moderate or calculated risk-taking involves a number of processes, stated below:

a) Understanding the situation

b) Gathering as much information as possible

c) Assessing one's own resources

d) Setting challenging goals for oneself, on the basis of the information and resources

e) Testing one's own abilities

f) Modifying the goals set on the basis of previous experience (one's own and others).

To be personally responsible for the risks involved in the establishment of an enterprise may be considered as one of the important dimensions of entrepreneurial behaviour. Entrepreneurs have, however, certain characteristic attitudes towards risk. Generally, the choice of an occupation is because of the 'fear of failure'. However, in the choice of an entrepreneur, the fear of failure forms the least important consideration. The entrepreneur bears the risk of launching a new business. Nonetheless, while opting for a risk, he does not like to play the gambler.

1.6.1 The Entrepreneur and the Gambler

The difference between a gambler and an entrepreneur needs to be clearly understood for a proper appreciation of entrepreneurial behaviour.

When a gambler takes risks, the person is primarily concerned with the pay off which is solely determined by the result of a "chance". The gambler operates without using the earlier experience. In gambling, such event is independent of any pay off.

On the other hand, even though the entrepreneur also stakes and hopes, he continuously intervenes to influence the outcome. In such a situation, the person is aware that any intervention, even in the most certain situations, makes all the difference to the outcome. Such awareness is confirmed by experience. It would be appropriate to say that an entrepreneur takes only such risks where one cannot control the outcome. The feelings or awareness, which is confirmed that the outcome can be controlled by interventions, marks the demarcating line between gambling and the calculated risk-taking.

In gambling, learning is not possible, whereas entrepreneurial risk-taking is mainly governed by learning. In the former, it is not possible to calculate long-term objective probabilities or odds. Such objective probabilities may be almost denied or not available to the entrepreneurial activity. Only the denial of the objective calculation of risk, however, does not make all the difference between gambling and an entrepreneurial venture. The sense of control, the possibility of learning, and the presence of moderate risk and subjectivity lead to entrepreneurial activity.

1.6.2 Moderate Risk Taking

The concept of taking a challenge or stretching explains better the concept of moderate risk-taking. One takes a challenge if the goal is personally meaningful, the outcome is dependent on one's effort, and the goal is a little beyond one's capabilities, holding in store a lurking possibility of even a failure. The same is true of the concept of' stretching'. One is likely to stretch oneself if the goal appears a little beyond one's reach, if it is personally meaningful, i.e. if it has any personal marginal utility, and its attainment largely depends on one's effort. Stretching results from the hope of success. On the other hand, a person with a low hope of success or a high fear of failure is likely to choose goals, which are well within one's capacity, thereby ensuring a low probability of failure. In the latter case, the concern is not about success or achievement, but about non-failure. Very often, by congenital standards, these people appear to be succeeding. In effect, they have chosen to operate well within their natural capacity. A person operating from the hope of success, however, is likely to increase the capacities because of inclination towards stretching.

1.7 SENSING OPPORTUNITIES

Let us understand yet another important problem faced in entrepreneurial life, “Sensing Opportunity” what is opportunity? It may be a chance to do something new; it may also be a way of getting something for nothing? or it may be a job or admission to a school or college. While these are, no doubt, opportunities, there is another type of opportunity that exists in our environment, which we most often fail to notice. We call it by the general term: problem Problems, pose a challenge to entrepreneurs, and in solving them, they find opportunities. For an entrepreneur it is like saying “If you have a problem, then it is my opportunity”.

Opportunities for launching new enterprises exist in the environment everywhere but all of us are not able to perceive them. Even if we do, we only see an opportunity in retrospect. The good idea was there but it is usually a case of “Why didn’t I think of it first?” Entrepreneurs however, perceive opportunities quickly, synthesize the available information and analyze emerging patterns that escape others. They are people with a vision, capable of persuading others such as customers, partners, employees and suppliers to see the opportunity, share it and support it. For them the opportunity exists, as we have seen before, in the environment in the form of needs and problems of people and society. After spotting the opportunity, they evolve a strategy to find a creative solution to the problem or need.

Apart from perceiving an opportunity that already exists in the environment, it is also possible to create or craft business opportunities. Many great inventions like the microwave and the mobile phones are the examples of created opportunities. They are born out of fantasies of entrepreneurs about products or services they would love to have in their lives. It requires lot of ideas which can be generated. We will now try to understand how these ideas can be generated and what are its sources?

1.7.1 Sources of Idea

By following different ways for generating ideas an entrepreneur collects a number of ideas. The process of generation of ideas can be streamlined by developing awareness for different 'Idea fields'. This helps the entrepreneur in enlarging the scope of thinking, at the same time structuring the ideas according to convenient frames of reference. Thus idea fields can be described as convenient frames of reference for streamlining the process of generation of ideas.

a) *Natural resources*

Ideas can be generated based on natural resources. A product or service may be desired from forest resources, agriculture, horticulture, mineral, marine or aqua mineral, animal husbandry, wind, sun and human resources. A further exercise with a field may generate many useful product ideas. For instance, if we are getting ideas in the field of forest resources, we can think of forest produce, wood-based product, bio-fertilizer etc. Similarly if it is horticulture, we can generate a number of ideas for food preservation, canning, freezing, juices, squashes, pulp, jam pickles etc. Similar exercises can be done with almost all the other natural resources.

b) *Existing products or services*

There is also a continuous and consistent effort on the part of all entrepreneurs to improve the products and services already in the market. When black and white computer screen came into use, immediately entrepreneurs started thinking of introducing colour monitors. There are new techniques and strategies being developed in every service like teaching, medicine, management etc.

So thinking about existing products and services can generate a number of ideas to improve them or to provide a cheaper substitute or to bring about a reduction in price. It can also help in deciding whether similar projects can be established, whether new products can work as raw material for existing units, whether new products can be developed from the waste or by products of existing units and whether there is scope for packaging and other services for existing products. For example, when an automobile unit is established in an area, attempts can be made to ascertain whether a few parts or components for the automobile can be produced in the small scale sector. Similarly where a perfume unit is functioning, there is scope for growing and supplying aromatic plants. Or essential oils can be purchased from existing units and final products such as medicine or cosmetic products can be manufactured. These types of backward and forward linkages of existing business activities are a good source of new ideas.

c) *Market-driven or demand-driven ideas*

We have already seen that one important method for generating ideas is to carry out a market research. Such a study yields valuable data about trends of supply, demand, consumer preferences etc. Sometimes information related to different products is available with associations and organizations, which carry out routine market surveys. Whatever the source of information about the market, it is a promising field for generation of ideas.

For instance, if through a market survey we learn that there is a gap between supply and demand for stationery in the beginning of school or college year, it can be a good opportunity to start a venture using this information. Similarly if the market survey reveals that a particular product is being imported, efforts can be made to find an import substitute. Indian space technology has witnessed a tremendous boost because of the development of indigenous technology.

In the service sector, it is booming time. There are many ideas that have transformed into reality. For instance, too much of pesticides, which is harmful for health, has given idea for organic farming. If for instance, a survey reveals that the call centres which are catering to the international clients are facing problems because of different accents like French, Italian American, a consultancy service to update employees of call centres through training in pronunciation may become a successful project. Similarly, if the market demands more of cheap detergent cakes, it will be a good opening for small-scale entrepreneurs. Though we are looking at market-driven ideas as an important field of entrepreneurial ideas, we should remember that market would always exert its influence on all enterprises. So entrepreneurs in all sectors have to be always knowledgeable about market dynamics.

d) *Trading related ideas*

Trading these days is not limited to ordinary grocers or distributor outlets. With increasing consumerism, the scope and nature of trade has enlarged; local trade, imports and exports, e-commerce etc. are all making trading a very wide area of enterprise. Trade in simple terms is buying goods and services, and selling them to consumers at a profit. One big advantage that trading has over other types of business is that it is easier to launch and less risky.

It is, however, necessary for a prospective trader to be aware of the trends in an economy. With the opening of the market to international companies, large size departmental stores, chain shops and umbrella markets have become ubiquitous – competition has become intense and to survive in the market new entrants will have to acquire skills, competencies and knowledge required to launch, manage and expand business opportunities. The basic concept, as we have already seen, is that if a business is to be successful, it must satisfy a need of enough consumers. A trade that is based on this concept is more likely to be successful than a trade that is launched without adequately studying the consumer needs.

e) *Service sector ideas*

What is the difference between entrepreneurs and employees? We have already examined this issue. Most of the people seek jobs to earn a living. They work for someone else and get salary or wage for their services. Such people are called employees. Entrepreneurs, on the other hand, are both owners and employees. So, when we talk about service sector ideas we should bear in mind this difference. We are not considering different options in service sector to launch a business venture that involves sale of services for a profit. The entrepreneur himself may provide the service sold or he may provide it through his employees. The key element is that he owns the enterprise and is hence ultimately responsible for its success or failure.

As said earlier, entrepreneurial opportunities are not restricted only to the manufacturing field. Service sector is the most growing field these days the world over, thanks to emerging knowledge societies and advances in information technology. Understanding the linkages to different business activities can identify so many new opportunities. For instance, with the existing industrial enterprises we can think of several service-based units like transport, workshop, painting, maintenance, security, catering, recruitment, training, communication etc. Similarly we can get ideas about linkages with commercial establishments like photocopy, courier service, printing, book-keeping, computer centre, telecom centre, advertisement etc. Many services that have the purpose of helping establishments satisfy their day to day needs like bill collection, water supply, water tank cleaning, travel arrangements, repair and maintenance etc. They can provide many useful options for prospective entrepreneurs.

1.7.2 Creating Efforts

We have understood that creativity is an important and key component of the talents and abilities needed for an entrepreneur. Apart from applying creativity to spot and harness opportunities, it can also be applied to develop new products and services. Such a function is often called inventive entrepreneurship. In a sense this field of opportunities overlaps with all other fields. There are basically five ways in which creative ideas can be generated:

1. Develop a new product or service.
2. Improve an existing product or service.
3. Find a new process or resource for manufacturing a product.
4. Find a new use for a product or service.
5. Find new markets for existing products or services.

A very useful concept to bear in mind is that most often creative products and services are born as a result of problem solving. Someone found that while tightening screws on fixtures, over tightening often resulted in damage to the fixtures. Here was a problem and the solution came in the form of a self-adjusting screwdriver, which prevented over tightening. Similarly when doctors found the monitoring of dosage of medicine to be administered to patients on a regular basis through the traditional method using a syringe cumbersome, a pharmaceutical firm developed a new process of implanting the required medicine in the patient for constant discharge of regulated and required dosage into the blood stream. When Israeli farmers faced the problem of raising fruit trees in arid and semi-arid conditions, they developed the now much-in-use drip irrigation system. An enterprising villager in our country adopted this system extensively to produce record yields on farms.

Another type of invention is to produce something completely new like computer, television etc. Even if an entrepreneur does not invent a product or service himself, he can spot good inventions, buy the rights, manufacture the product and sell it. We have already seen an example of this kind of opportunity in Trever Baylis clock-work powered portable radio.

1.7.3 SWOT Analysis

Once an idea for a business gets generated, it is important for an entrepreneur to go in for a SWOT Analysis about the idea. This is important as it helps the entrepreneur to make a feasibility study before starting the business. This is crucial and important.

Let us understand from a case study how a business opportunity can further be analyzed for making a final decision. Read the case and try to do the following exercise.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

CASE STUDY

The Pickle Maker

Ramvati hailed from a village of Uttar Pradesh and was married to Sanatan of Rajasthan. Ramvati always wanted to do some work and earn money to increase the family income. After seeing the women in her village mostly engaged in some activity or the other, Ramvati also thought of making pickle and selling it to the market. She thought it would be a good idea as she knew how to make good and tasty pickle and moreover, she need not have to go out of her house to make it. She may not need to invest a lot of money and the technique needed for making pickle was also very simple.

There was a potential market nearby her village and she thought that her pickle could be sold there. She felt that she should brand the product (like Ramvati Pickle) so that selling becomes easy and fast. She also found out that people in the town and nearby villages use lot of pickle as a regular food habit. She thought she can make a variety of pickles to suit different customers taste – “extra spices”, “sweet pickle” and “pickle of various vegetables”. However, Ramvati realized that the raw materials needed for making pickles are mostly seasonal and therefore, she needs to have a large stock. There was also a problem as pickle can be spoiled if not prepared properly. It has to be consumed very fast. Her husband Sanatan also told her that she needs to go for a licence as it is a food item. Ramvati thought she would visit the market and find out something more about the product. She also discovered that there are many women who are making pickles and selling them in the market. She also realized that people who buy pickles mostly go for a brand name which is common and popular. After coming home Ramvati started thinking whether she should go in for pickle making or not!

Try to fill in the following box. Identify the Strengths, Weaknesses, Opportunities and Threats for the Pickle business for advising Ramvati. This is known as SWOT analysis.

SWOT Analysis

Strengths	Weaknesses
Opportunities	**Threats**

Look at the answers at the end of the Unit.

1.8 ENTREPRENEUR AND ECONOMY

The growth of economy in any country is largely dependent on its people and these people are using resources for a productive purpose. The entrepreneur is an economic leaders. According to Joseph Schumpeter, who regarded entrepreneur basically as an innovator who carries out new combinations to initiate and accelerate the process of economic development, Innovation may assume the following forms :

i) Introduction of new goods;
ii) Introduction of new methods of production;
iii) Opening of a new market;
iv) Conquest of new source of raw materials or half manufactured goods; and
v) Carrying of new organization of any industry.

The innovator differs from the manager of a firm who runs the business on established lines. The entrepreneur is the engineer of change, not its product. Profits are the premiums for innovation and continue only when one keeps one step ahead of rivals with innovations.

Schumpeter's theory is based on certain assumptions like existence of capitalist society with private property, private initiative, money and banking system, etc. The applicability of this theory is doubtful in under-developed countries where the poor infrastructure and lack of capital may block the innovativeness. In such countries even imitator entrepreneurs have a distinct role to play. Such entrepreneurs provide a fillip to the process of economic growth by adopting business practices already discovered and applied. They reduce the shortage of goods and services and create additional jobs for the unemployed.

India is a country where entrepreneurial initiatives are now encouraged. There are lots of institutions, Organisations, both technical and non-technical, are giving training to young people to become entrepreneurs and create job opportunities for others. So, why not become an entrepreneur to bring a positive change to the society.

1.9 FOOD PROCESSING BUSINESS

In order to understand what it means to be self-employed in food processing, let us see what one needs to know and needs to do.

Food processing business has to consider the availability of raw material, quality, packaging, and preferences of consumers. Generally, we all prepare food at home, and also make food items, which are preserved for a long time. In rural and urban areas, men and mostly women make dried, fermented, and fried products for their family consumption. Adding some skill and knowledge of preservation, anyone can start a business in food items.

It is important to have an idea of

First

- Where one could get trained in food processing
- Where one could get training in business management.
- Where one could get awareness business aspects of the project.

Second

- Raw materials
- Availability of raw material in local market
- Availability of the raw material outside local market
- Price
- Transport
- Equipment

Third

- Packaging
- Type of packaging
- Attractive labelling

Fourth

- Storage
- Preservatives
- Space

Fifth

- Marketing the Product
- Distribution
- Publicity

Sixth

- Preparation of Project report
- Arranging Finance

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

SENTENCE COMPLETION TEST

Tick any one

1. To succeed in life, one needs

   a) money
   b) friends
   c) self-confidence
   d) good luck
   e) skill

2. If there is a good demand, it requires ….. to earn in business

   a) proper instructions
   b) quality product
   c) intensive and good advertisements
   d) capacity to store goods
   e) own control over market

3. My main aim in running industry should be

   a) to keep workers happy
   b) to earn good profit
   c) to improve quality of products
   d) to remain undisturbed by strikes and unrest
   e) to work hard

4. To continue progress, it require

   a) hard work
   b) new and progressive ideas
   c) honesty and trustworthiness
   d) education
   e) systematic and though work

5. He became a successful industrialist because

   a) he knows how to maintain relations
   b) he has dependable friends and relatives
   c) he has vision and enterprising nature
   d) market fluctuations were favourable to him
   e) he is a gentleman and a good businessman

6. I want to start a new business because

   a) I should earn
   b) I would be popular in society
   c) I want to do something new
   d) The state wishes that we should do something
   e) I want to serve my caste and society

7. Slow economic progress of the country is because of

   a) Faulty policies of the government
   b) Lack of good facilities
   c) Lack of someness venture
   d) Labour unrest
   e) Lack of increasing opportunities

8. If I will face difficulties in my work, then

   a) I will leave it and will start a new work
   b) I will take advice of known and proper person
   c) I will think why it happened, and then again will work with new Enthusiasm
   d) I will blame my colleagues
   e) I will blame my self

9. If business fails or there is a loss, then

   a) I shall try to pay less tax to reduce the loss
   b) I will accept it with sportsmanship and try again
   c) I will sell goods at cheaper price so that everything is sold out
   d) I will join with somebody in partnership
   e) I will try to find out who is responsible for the failure

1.10 LET US SUM UP

Deciding a career is important. However, there are lots in benefits in becoming a self-employed person. It generates income and this is responsible for livelihood. It helps to be innovative and growth-oriented. The growth in a self-employed situation reflects certain entrepreneurial behaviour. In this process, an individual learns to imbibe many entrepreneurial qualities and to acquire certain entrepreneurial skills.

'Risk' is inevitable in the life of an entrepreneur "Risk" in other words refers to challenges but the risk taken by an entrepreneur has to be moderate and calculated. However, entrepreneur's risk is different from gambler's risk although gambler also undertakes risk. But remember that an entrepreneur depends on "effort" for the outcome, while the gambler depends on "chance".

The success of an entrepreneur depends upon the goal setting with a hope of success. This leads to stretching to one's own capacity. The capacity would include how one senses opportunity. The sensing of opportunity involves understanding problems in the environment, and identifying a solution, think about ideas, products and services. All opportunities have to be analyzed through SWOT analysis. The feasibility of a business can only be understood through that process.

Becoming an entrepreneur also means a contribution to the economy of a country through new products, new methods, new markets, and new sources of material. This involves innovations. However, in a developing country like India "imitators" can also be entrepreneurs.

1.11 KEY WORDS

Accelerate	:	Begin to move more quickly
Attainment	:	Success in accomplishing
Conquest	:	The action of conquering
Distinct	:	Recognizably different in nature
Gambler's risk	:	primarily concerned with the" pay off" which is solely determined by the result of a "chance".
Imitator	:	Copier of a model
Inclination	:	Natural tendency or urge to act or feel in a particular way
Innovate	:	Make changes in something already existing
Oriented	:	To direct towards
SWOT	:	A process through which the feasibility of a project/business idea is assessed
Sensing of opportunity	:	understanding problems in the environment, and identifying a solution, thinking ideas, products, services.

1.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

CASE STUDY

SWOT Analysis Chart

Strengths	**Weakness**
• The Pickle can be made tasty • Low investment • Skills easily available • Simple technology	• Seasonality of raw materials (needing large stocks) • Product is perishable • Licensing formalities are cumbersome
Opportunity	**Threats**
• Large Market • Brand selling possible • Variety could be made to suit customers 'Tastes'	• Large no. of competitors • Establishing brand is difficult • Customer tastes may change

Remember that Weakness can be converted into Strengths and Threats can be converted into Opportunities

Check Your Progress Exercise 2

GET YOUR SCORES FOR SENTENCE COMPLETION TEST

1. To succeed in life, one needs: self-confidence (c)
2. If there is a good demand, it requires: Quality Product (b) to earn in business.
3. My main aim in running industry should be to earn good profit (b)
4. To continue progress, it requires new and progressive ideas (b)
5. He became successful industrialist because he had vision and enterprising nature (c)
6. I want to start new business because I should earn (a)
7. Slow economic progress of country is because of lack of someness venture (c)
8. If I will face difficulties in my work, then I will take advice of known and proper persons (b)
9. If business fails or there is loss then I will accept it with sportsmanship and try again (b)

Make a total of the statements tick marked in the answer sheet by you. Then follow the table given under for final scoring.

Table

0 – 3	=	1 mark
4 – 6	=	2 mark
7 – 9	=	3 marks

Note: If your scoring is in category 7-9 you get 3 marks: **It suggests that your understanding about entrepreneur and entrepreneurship is towards right direction.**

If your scoring is in category of 4 to 6 you get 2 marks: **It indicates medium score.**

If your scoring is in category of 0 to 3 you get 1 mark: **It is a low score.**

In order to improve the score read lot about entrepreneurs, try to meet them, watch Television programmes on them. Try to locate new food products in the market. Try to find their source.

1.13 SOME USEFUL BOOKS

1. Akhouri, Mishra; Sengupta. R. (1999) Trainers Manual on Developing Entrepreneurial Motivation Published by NIESBUD.
2. C.B.S.E. (2002) “Entrepreneurship Class XI & XII”.
3. Gupta, C.B. (1992) Entrepreneurial Development, Sultan Chand & Sons.

4. Jain, P.C. (Ed.II) (1999) Handbook or New Entrepreneurs, Oxford University.

5. Khanka, S.S. (2004) Entrepreneurial Development, S. Chand & Company NISIET, Hyderabad.

6. Raju, U.B. and Rani, C. (Ed.) (2002) Women Entrepreneurs in India, Published.

7. Raymond, W.Y. Kao Tan Wee Liang (2001) Entrepreneurship and Enterprise Development in Asia, Prentice Hall.

UNIT 2 ENTREPRENEURIAL SKILLS

Structure

2.0 OBJECTIVES

After going through this unit, you should be able to:

- appreciate the requirement of becoming an entrepreneur;
- explain the concept of entrepreneurial skills;
- describe entrepreneurial values, attitude and motivation; and
- state various entrepreneurial skills.

2.1 INTRODUCTION

Entrepreneurship is the quality and skill required to become an entrepreneur. It refers to identifying and innovating ideas and services; mobilizing resources; organizing production and services; and finally marketing them, covering the risk by constantly trying for growth and development.

In this unit we will try to understand the concept of entrepreneurial skill and different skills that an entrepreneur needs to develop.

2.2 THE JOY OF BEING AN ENTREPRENEUR

In the previous Unit you have understood who an entrepreneur is. However, let us also understand the joy that a person gets after becoming an entrepreneur. In entrepreneurship the individual is the most important element. He/she takes a decision to start an enterprise and strives to make it a success. In this process, it is an experience of challenge, joy as well as fulfilment. Let us look at the reasons why this is an experience of fulfilment.

- An entrepreneur is an independent being; entrepreneurship provides an opportunity for self-expression and the realization of one's passion for doing something new and different – a scope for innovation.

- There are numerous opportunities for self-development.

- An entrepreneur makes his/her own decisions and acts on them.

- Working on one's own and thus getting rewards yields immense satisfaction and pleasure for more than what one can get in a job.
- Monetary rewards can be more that commensurate with one's capacity, capabilities and work.
- An entrepreneur with a science and technology background can introduce new technologies, develop substitutes for imported components.
- An entrepreneur generates employment for others.
- An entrepreneur can make significant contributions to the development of the country.
- An entrepreneur can be doubly fulfilled. He/She realizes both goals, of individual success as well as of contribution to society.
- Above all he/she can be an achiever, realize his/her goals and prove his/her one's achievements to the world.

The following example shows how a person with determination and strong desire to be on his own can become an entrepreneur and be successful:

Balachandran was born in a lower middle class family of Madurai. He completed his graduation in commerce by attending evening classes and doing part-time jobs during the day. Later, he worked as a part-time accountant and also became an insurance agent. He left this job due to some problems and enrolled himself in a post-graduate course in Commerce. But his heart was not really in it. It was at this time that he came across an advertisement for an Entrepreneurship Development Programme (EDP) to be organized by ITCOT (Industrial and Technical Consultancy Organization of Tamilnadu Ltd.) He applied for participation in the same and was selected. During the EDP he identified a project, but could not mobilize the financial resources needed. However, he was determined to set up his own industry and with this objective he left for Chennai in 1988 with just Rs. 500 in his pocket.

He was unfamiliar with that city, but somehow found an inexpensive place to stay. In order to servive, the first priority was to earn some money. With some knowledge about the market for used cartons, he purchased used empty cartons at a cheap rate from liquor shops and sold them. This went on for some time; then through a friend he got a job, as an assistant to a commercial artist, which paid him Rs. 300 per month.

But his ultimate aim was to establish his own enterprise. So before joining he tried to find out whether a job would provide him experience, which could help him, set up his own enterprise. When he found that there was a good market for advertising, he joined. His job was to procure orders for the artist and on the very second day of his employment, he procured a very large order. But his salary was too small to survive on, so he procured small orders for himself on the side and executed them. Very soon, dissatisfied with his salary he took up another job with a liquor company inspecting liquor shops, but continued with his work for advertising companies. And when he felt that he had enough work to survive on, he resigned his job.

In December 1988, with a sum of Rs. 24,000 borrowed from his brother-in-law, he was finally able to launch his own advertising enterprise in rented premises. The first order was from Kwality Ice Cream. Working capital was a problem, but with persistence he obtained Rs. 5,000 from a bank. Fortunately the machinery and equipment required were few and not very expensive, so he had some money left over for the working capital. The business grew steadily.

By 1990, he had diversified into acrylic glow sign boards and was executing orders for big companies like Cadbury's, Kwality Ice Cream, etc.

He thus grew steadily, took more loans from banks, diversified into name plates, menu boards, engraved works, screen-printing and bulk order paintings.

From humble beginnings, step-by-step, with hard work and perseverance, today he is an entrepreneur with a turnover in lakhs. Two years ago he launched a confectionery unit. But the story does not end there for Balachandran. He has ambitious plans for setting up other industries too, and with his skills and motivation, he is bound to succeed and realize all his dreams.

So, does this case motivate you to become an entrepreneur?

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

Tick the right answer

1. Do you feel motivated? … (Y/N)
2. Do you sincerely believe that you have to work hard? … (Y/N)
3. Can you identify some entrepreneurs, from your surroundings, who are reaping the fruits of their labour? … (Y/N)
4. Do you put your belief into action? … (Y/N)
5. Can you identify the types of work you have to do? … (Y/N) List them.
6. Can you work for long without getting tired or bored? … (Y/N)
7. If the answer is 'NO' to 7, have you adopted any strategy to improve it? … (Y/N)
8. Is your work related to the attainment of your goal? … (Y/N)
9. Do you call yourself a hard worker? … (Y/N)
10. If 'Yes' to 9, do you have reasons for thinking so? (Y/N) Write down the reasons.
11. Is there any gap between how you want to pass a day and how you actually do it? … (Y/N)
12. Have you mastered the play theory of work? … (Y/N)
13. If 'Yes' to 14, do you have any concrete evidence? (Y/N) list out the evidence.

2.3 WHAT IS REQUIRED TO BE AN ENTREPRENEUR?

Once you are motivated you will start your business. It is often said that in order to start a business one need to have three things: knowledge, attitude and skills. For example, if a person wants to start a fruit juice corner, he should have proper knowledge about "processes" involved in fruit juice making. What kind of fruits make juice, in what season, which fruits are available etc. are the knowledge part. Apart from this the skill to prepare fruit juice, using machinery etc. is important, this is the skill part. To prepare oneself, to 'Be' a fruit juice stall owner, to have the right mind set and willingness to be independent and value each and every job involved in this business. This is referred as attitude.

It is the attitude that matters

Why is it so? There is nothing wrong with rummy or any other thing. The difference lies in the attitude of the players. You associated the idea of boredom with rummy because you learnt to hate it; others associated it with pleasure as they learnt to love it.

It is implying this. Turn the switch in your mind. The boring job turns out to be the most interesting: Change! Does it come easy? With time, anybody can change. Given the will, you too can change!

You have to change your attitude. You have to find interest in your work – whatever you are called upon to do. It is all because you have not got used to it at all. That is why it is wasted. Start using it and interest will develop.

Right now start finding your work interesting and enjoyable. No matter if it does not seem to be so. You simply start thinking it is wonderful. You know that drops of water wear away the hardest of stone. Likewise, each day of your practice will carry you closer to your goal.

Every day, while you work, try to visualize the goal you are striving for. Each spell of work will take it nearer to its fruition. The intensity of your desire should be so strong that it will take away all the rigours of your so-called hard work. Then it will turn into mere play and sheer fun. Imagine, feel and experience that fun, that joy!

Make work fun!

Believe that you can do it!

Start doing it right now!

Brush aside the initial difficulty, if any!

Create enough zeal and enthusiasm for your work!

Each day, conquer it with greater determination!

A simple book on 'Yogic exercises' warns the beginners: "In the beginning, you will not be able to perform some of the poses perfectly. Regular practice for some days will bring perfection. Patience and perseverance, earnestness and sincerity, are needed."

Contd…

We interviewed a circus star. Since childhood, she had put in many years of strenuous practice. It took time, patience and devotion to achieve perfection. Practice makes for perfection.

Entrepreneurs who are already successful, about whom you hear or read stories, benefited from many years of informal training. Real education does not necessarily mean university education, alone.

These many years of informal training you do not have. And in your case, it is this training we are going to replace with a compressed course. Naturally, you can imagine the importance of following each instruction faithfully, as well as the amount of work you have to do in order to obtain the desired result in the shortest possible time.

There is another difference. Our entrepreneurs had their informal training in its most natural form, whereas you have to be deliberately induced into it. Therefore, quite possibly, you may have to exert a lot more than they did.

That is why it is all the more important that you should turn the tedious task of exertion into an interesting play. Obviously it has other benefits as well. That way, you will learn better and quicker. It should provide an ideal substitute for another man's informal training.

2.4 CONCEPT OF ENTREPRENEURIAL SKILLS

If you decide to become an entrepreneur, it is natural that you need to develop certain entrepreneurial skills to translate your dreams into action. What are these skills and how they are developed are certain questions that might bother you. However, we will first try to understand entrepreneurial skills.

Entrepreneurial skills refer to the ability and the capability of an entrepreneur to initiate, launch and sustain the process of enterprise building. These skills are not necessarily born but can be developed.

However, these entrepreneurial skills are the result of certain set of values, attitudes and motivation.

2.4.1 Entrepreneurial Values Attitudes and Motivation

Values

Values refer to one's own belief towards life in general. It helps an individual to focus towards goal. However, some of the entrepreneurial values are as under:

- Innovativeness
- Independence
- Seeking Perfection, and
- Respect for work

Attitudes

Attitude refers to ones own in born and developed tendency to think and act in a particular way. The entrepreneurial attitudes are:

- To use imagination/intuition
- To take moderate risk
- To enjoy freedom of expression & action
- To look for economic opportunities
- To find satisfaction from successful completion of tasks
- To believe that one can change the environment
- To take initiative
- To analyse situation & Plan Action
- To involve in work

Motivation

Motivation is generally understood as the driving force towards the attainment of the goal. Because of certain entrepreneurial values and attitudes specific motivations get developed within a person. Such as:

- Constantly striving for success in attaining certain standard of excellence.
- Desire to set some standard and to excel it.
- Need to excel the standard already set by others.
- Concern for achieving something unique.
- Urge to succeed in achieving long-term career goals.
- Need to influence environment, individuals & situation for achieving set goals.

In the next unit you will know more about Motivation with particular reference to Achievement Motivation.

2.4.2 The Work Ethics

The Primary Motive of an entrepreneur is related to his/her work or task and therefore, the basic philosophy of work is important for an entrepreneur. Let us understand about the work ethics.

Who works? The man who has a need. Everybody in the world from a Sadhu and a politician down to the writer, builder and carpenter, and whosoever, works with a motive. There is no work without a motive. Not even the so-called “nishkama karma”. However, motives differ from man to man. A sadhu has a motive different from that of a politician.

We are mainly concerned with economic motives. We are interested in economic wants and our work is economically directed towards productivity, prosperity and plenty.

Want, necessity, need or desire – whatever you may call it – is the great force behind all human motivation. No skyscraper would have been built, nor better living conditions created, had there been no felt-need.

Needs may arise because of:

a) a desire for material gain;

b) a desire for winning love;

c) a desire for gaining a sense of freedom and power;

d) a desire to be better than your neighbour;

e) a desire for social and national service;

f) a desire for self-expression and recognition.

Identify the ground (or grounds) for your need. Specify them. This will serve as your motivators.

The biggest source of energy – far greater than all potential sources of energy combined together – mankind could so far find, is the desire of the human heart. It fuels the gigantic engine of progress. Any man fuelled by the fire of desire moves to ever greater achievement. The man devoid of the fire of desire rots in the same groove he was born.

Invent your necessity

Invention is not first. Necessity is the first. And desire comes ahead of development.

In order to rise higher, to achieve greater success, develop your fuel first. Before you build anything, build up as your desire.

L.N. Kirloskar was a petty drawing instructor at Victoria Jubilee Technical Institute (VJTI), Bombay. Since the time of Kirloskar, if not earlier, many such drawing instructors retired from service and died as drawing instructors. At present, a few hundreds, if not more, such instructors are serving in different institutions in the country. Probably they too will retire and die as drawing instructors.

But Kirloskar did not retire as a drawing instructor. And he did not die too as one because he had the courage to desire something much more than the pittance he was getting at VJTI. He had a dream to fulfil. He had the will to work for it. As a result he died as a renowned industrialist. Remember, today's conditions are much better than those in Kirloskar's time.

Y.R. Nanda was a small-time trucker. He fell in love with a girl named Dolly. She told her young fiancé in plain terms that she would never marry a truck driver'. Nanda set up Escorts Limited in 1949 in order to win his fair lady's hand. This is no fairy tale. It is a true story.

It does not matter what you are at present. It matters what you want to be.

Spell out your wants, necessities and desires. Make them strong and intense. If you are armed with a burning desire, only then will you be able to work wholeheartedly with a tenacious singleness of purpose, and win. The stronger the desire, the higher you will reach.

2.5 UNDERSTANDING ENTREPRENEURIAL SKILLS

In order to initiate, launch and manage the enterprise, the entrepreneur is motivated to imbibe certain skills. Let us try to understand these skills, which are important for success.

Positive self concept

An achiever directs his energies towards accomplishment of worthwhile goals and sets standards of excellence in what he is doing. This is based upon the awareness of his strengths and weaknesses. He uses positive knowledge to support his thinking. He is rarely negative. He has self-confidence.

No entrepreneur has all these qualities. But most of them possess at least some of them. So the first step for a person aspiring to entrepreneurship is to make an inventory of the traits he possesses. This self-awareness analysis will help define your strengths and overcome your weaknesses.

Creativity and innovation

The anchor of an entrepreneur's career is creativity and innovation. Innovation is the process of applying **"new knowledge"** to practical use. It does not necessarily mean trying new ideas for the first time but it also means applying the same or a similar idea at different places or in new settings. As an entrepreneur you may have to develop the quality of picking up new ideas and adopting them faster than others.

Risk taking

Many of us have new ideas, knowledge and resources. But we do not start an enterprise because we lack the quality to take risk involved in it. As an entrepreneur you have to develop faith. No venture is possible without certain amount of risk. An entrepreneur assesses the risk and favours taking calculated moderate risk (neither very high nor very low). Risk means stretching ones own capacity where the chance of success is greater than the chance of failure.

Using feedback

Entrepreneurs like to have immediate feedback on their performance. They seek prompt and accurate data, and it does not make any difference whether or not the information they get is favourable. In fact, they are stimulated by unfavourable feedback into pouring more energy into attaining their objectives.

Opportunity seeking

Common people just wait for opportunities to come along. Majority does not even recognize opportunities until these become obvious. An entrepreneur actively looks for, seeks, recognizes or creates business opportunities even under crisis.

Information seeking

Seeking relevant and precise information is important for success. It enables you to take risk, helps improve the quality of decision that you make and provides basis for efficient management. An entrepreneur inculcates the habit of gathering information from all sources and considers expenses for seeking information as investment.

Being high achiever, an entrepreneur has ability for seeking and using feedback about his own performance. Based on the feedback, the person mends his ways. Often money (profit or loss) is an indicator of the performance.

Concern for standard/quality of work

The concern for excellence is the key quality of an entrepreneur. By attaining certain standard of excellence in his work, and proving his worth he gets satisfaction. Sub-standard performance is not acceptable to him. The standard of work performance is not limited to products and services, but extends to efficiency, to do things better, faster, with fewer resources.

Problem solving orientation

One of the important entrepreneurial qualities is the problem-solving orientation. While pursing any business goal, an entrepreneur makes the basic assumption that problems are bound to be there. As a matter of fact, he believes that real pleasure comes in solving these problems. Accordingly, entrepreneurs develop a lifestyle of solving problems.

Faith in planning

To be a successful entrepreneur you need to develop skill in planning and a firm faith that planning is a must for successful completion of any task. You develop and use logical step-by-step plans to reach your goal. Through planning an entrepreneur prevents the wastage of scarce resources, ensures success by anticipating possible hurdles, locates new sources of help and resorts to alternative activities to reach the goal.

Persuasive and influencing quality

One of the important functions is to influence the environment comprising individuals and institutions for mobilizing resources, procuring information, organizing production/services and marketing your products and services. For all these you need to develop skills and attitude for persuading, influencing and convincing others.

Long term commitment

This is one of those characteristics, which distinguish you as an entrepreneur, as the creator and builder of an enterprise from the promoter of quick money. The commitment to a long-term entrepreneurial goal helps an individual to give highest priority to getting jobs completed.

Coping with stress

As a central figure in your enterprise, you will have to cope with many situations at the same time and make the right decisions, which may involve a lot of physical and emotional stress. All this can be done, if you have the capacity to work long hours and keep cool under a lot of tension.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

CASE STUDY

Let us study the case of Ajay. Can you list out some of the qualities in him which have made him a successful entrepreneur.

Story of Ajay

Ajay after his higher secondary started working in a Private Company. However, he nurtured a dream to have his own enterprise. The training during November, 2001 in an EDP on Food Processing organized by a consultancy organization helped his dream to be come true with the aid of Cooperative Agricultural and Rural Development Bank Ltd. Ajay set up his enterprise “DELICIOUS” Food products in December 2001 at village Hariharpur, (Midnapore). However, like any other entrepreneur, he had initial difficulties in launching the enterprise. This process made him strong and determined and he was able to start the enterprise with an initial investment of Rs. 2 lacs with a matching loan of Rs. 2.50 lacs. He collected information about a machine developed by IIT Kharagpur at the Department of Food and Technology; this was a motorized oil-extracting machine, which he felt would help him to create a healthy snack item. The capacity per day of this machine was 300 kgs. He purchased the raw material from the wholesale market of Kolkata as quality and cost effectiveness were his prime concern.

The food item that he produced got picked up by the market and within a period of 2 years, the unit could establish its identity and reputation. For Ajay there was no looking back and he expanded his market to Bihar and Orissa, apart from the local market and identified about 26 distributors with 19 full time workers. As time passed, Ajay expanded his business and identified more smack items. After a training program me during March 2002 by the KVIC, he decided to diversify his business. His colleague Vipin, a Food Processing Expert of Kolkata helped him to add value to his product.

At the present moment Ajay is happy with his reputation in the market but the fund flow and cash liquidity is not helping him to fulfil his next dream. He is aware that these are the problems of any business when it grows and he has to persevere.

Ajay is ready with his new venture of starting a unit of grinding mill with Vipin as his partner. The Bank is ready to finance the Project but is insisting on a market study done by an established organization. The dilemma at this stage for him is whether to invest money on a Market Study or to concentrate on present business. He strongly feels that this consultancy organization being the Promoter of his initiative should give him concession in consultation charges. The journey to becoming an entrepreneur has made him tough and he is open for negotiation.

Perhaps it is time for Ajay to consolidate his business strategy and review the marketing expansion for his principal business. For an established entrepreneur nothing comes free, but perseverance is tested.

(Case extracted from a report of NIESBUD)

In case you have identified a few skills in Ajay, Check the same with the answers given at the end of the Unit.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

"Entrepreneurial Skill Assessment Quiz"

This quiz is designed to determine the latent skills in you. Read each question and respond by indicating 'T' for true or 'F' for false. Give your immediate reaction. Be completely honest so that the quiz will really be useful to you. Complete the quiz in one sitting free from distractions.

True/False

1. When faced with a problem, I always find a new way of overcoming it ________
2. When a decision has to be made, I can make it easily even though I am not sure of the outcome ________
3. I have a strong need for social interaction ________
4. After learning how to do something right the first time, I don't change my approach ________
5. I have a plan where I want to be financially ten years from now ________
6. When I am placed in a new situation at work I quickly sort out what needs to be done ________
7. I see potential problems as challenges ________
8. Constantly having to deal with problems wears me down ________
9. I revise my goals from time to time in the light of changing situations ________
10. It is important for me to know that I have a dependable income ________
11. When I am dealing with a problem, I tend to to get struck easily ________
12. If I were laid off, I know I could find some other source of income ________
13. I thrive on the challenge of solving different problems ________
14. I don't enjoy being directed by others ________
15. I take courses on how to improve what I do ________
16. Once I've met a challenge I am usually satisfied and don't need to look for an other project ________
17. I normally start off my day with a list of things to do ________
18. I don't enjoy working alone ________
19. The fear of losing my job causes me great apprehension ________
20. I am not good at dealing with a multitude of problems at the same time ________

21. I consider myself to be very resourceful in tight situations __________
22. I usually have a plan of action before starting a project __________
23. I am good at finding creative ways of solving problems __________
24. The idea of being my own boss appeals to me __________
25. At times, I don't feel completely comfortable with myself __________
26. I worry about what will happen if my plans to do not work out __________
27. When I come up against un-expected obstacles, I prefer not to continue __________
28. I have a strong desire to improve myself in everything I do __________
29. I read books on how to achieve success __________
30. I need to keep taking on challenges and feeling myself overcoming them __________
31. I think of a glass as being half-empty rather than half full __________
32. I get disappointed when things do not go my way __________
33. I believe in the saying "If anything can go wrong, it will" __________
34. My friends would call me an optimist __________
35. I always look at the bright side of the life __________

2.6 LET US SUM UP

Most individuals are looking for many things when they venture out on their own. Some of the charms of becoming an entrepreneur are:

- Opportunity to gain control over your own destiny
- Opportunity to realize your full potential
- Opportunity to reap unlimited profits
- Opportunity to contribute to society and be recognized for your efforts.

To become successful as an entrepreneur, one needs to have specific skills. These skills get developed in a person by certain set of values, attitudes and motivation. Values are certain beliefs, which give direction. Attitudes are defined as certain tendencies to act. Motivation is the driving force, which helps an individual to acquire certain skills, which are functional, and helps the individual to perform.

The entrepreneurial skills are important as they help the person to prepare himself for the external environment. These skills can be learnt and can be developed through proper training and interventions. Some of the skills are important to launch any business whereas some are important to manage the enterprise. or example seeking and using feedback, concern for standard/ quality work, problem solving orientation, persuasive and influencing talents are very important in sustaining the entrepreneurial initiative.

2.7 KEY WORDS

Entrepreneurship : The quality and skill required to become an entrepreneur.

Entrepreneurial skills: The ability and the capability of an entrepreneur to initiate, launch and sustain the process of enterprise building.

Values : One's own beliefs towards life in general

Attitude : One's own tendency to act towards the goal and direction.

Motivation : The driving force towards the attainment of the goal.

Innovation : The process of applying "new knowledge" to practical use.

Risk : Stretching one's own capacity where the chance of success is greater than the chance of failure.

Persuade : Cause another to do or think in a desired way through reasoning or argument.

Convince : Cause another to believe firmly in the truth of something.

Influence : The capacity to have an effect on the character or behaviour of someone or something, or the effect itself.

Achievement Orientation : Desire to do something, which is new or better, and to be the best in competition.

2.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISEs

Check Your Progress Exercise 1

Clues

1. It should be a continuous process.
2. For 2 to 11, 13 and 14, a "Yes" answer indicates good progress.

   For 11 and 14, proofs will confirm your 'Yes' answer.

   Any contradiction among 6, 9, 10, and 11 will indicate that you are not able to judge yourself properly.

'No' answer in 12 proves that your action and will are perfectly matched. Your will power is quite strong. Keep it up.

A 'Yes' answer to 12, you have to take remedial action for reducing the gap.

Check Your Progress Exercise 2 – Case Study

Story of Ajay

The following qualities\skills have made Ajay an Entrepreneur.

- Having a dream (Achievement Orientation)
- Strong
- Determined
- Hard Working
- Information seeker
- Long-term commitment
- Risk Taker
- Persevering
- Problem Solver
- Planner
- Persuasiveness

Check your Progress Exercise 3 – Self Exercise

Check Your Score

(Tick mark as per your response True\False)

SKILLS

Innovation	1(T), 4.(F), 11(F), 5(T), 21 (T)
Tolerance to Uncertainty	2(T), 6 (T), 10 (F), 12 (T), 19. (F)
Desire for Independence	3(F), 14 (T), 18 (F), 24 (T), 25 (F)
Continuous Goal Setting	15.(T), 9 (T), 16 (F), 17 (T),, 20 (T)
Persistent Problem Solving	7 (T), 8 (F), 13 (T), 22 (F), 23 (T)
Achievement Oriented	26 (F), 27 (F), 28 (T), 29 (T), 30 (T)
Positive Outlook	31 (F), 32 (T), 33 (F), 34 (T), 35 (T)

The result

Add up your tick marked scores in each category of skills. The score obtained may help to understand your position & status on different skills. If your score is 5, congratulations!! If your score is less than 3 it suggests that you need improvement in that skill. Find out the way for developing the same. However, the next unit will help you to see the way of developing these skills.

2.9 SOME USEFUL BOOKS

1. Akhouri, Mishra; Sengupta. R. (1999) Trainers Manual on Developing Entrepreneurial Motivation Published by NIESBUD.

2. C.B.S.E. (2002) "Entrepreneurship Class XI & XII".

3. Gupta, C.B. (1992) Entrepreneurial Development, Sultan Chand & Sons.

4. Jain, P.C. (Ed.II) (1999) Handbook or New Entrepreneurs, Oxford University.

5. Khanka, S.S. (2004) Entrepreneurial Development, S. Chand & Company NISIET, Hyderabad.

6. Nalinaksha Mutsuddi (1996) You Too can become an Entrepreneur, Wheeler Publishing.

7. Raju, U.B. and Rani, C. (Ed.) (2002) Women Entrepreneurs in India, Published.

8. Raymond, W.Y. Kao Tan Wee Liang (2001) Entrepreneurship and Enterprise Development in Asia, Prentice Hall.

UNIT 3 DEVELOPING ENTREPRENEURIAL SKILL

Structure

3.0 OBJECTIVES

After going through this unit, you should be able to:

- explain the stages of developing the mind set for becoming an entrepreneur;
- describe about Locus of Control; and
- state the steps of planning for success.

3.1 INTRODUCTION

As we have understood from our previous units that it is possible to acquire Entrepreneurial skills, in this unit we will understand the process of acquiring them. Remember the saying" GOD help those who help themselves" it holds true in the case of becoming an entrepreneur.

3.2 RIGHT MINDSET

In order to become an Entrepreneur, all you need to develop is the right mindset, the appropriate knowledge and required skill. I am sure you will agree that it is not so difficult to collect information in the era of internet, apart from books and journals, which are the old device. Acquisition of skill related to business function is important and it can be learnt. However what is most crucial in this is to develop a right kind of mindset. Let us look into the following.

3.3 STRATEGY TO BRING DESIRABLE CHANGES IN THE "MIND SET" THROUGH TRAINING

It is possible to bring desirable changes through a purposeful training intervention. We have talked about this in the previous unit. The specialist trainer organizes specialized training. However the major responsibility lies with the learner for this to succeed. The attempt is made to provide an opportunity to explore the "Behaviour "and experiment with new Behaviour conducive to entrepreneurial performance. These lead to getting entry into the process of "self- learning" and "self-acceptance". Now let us understand this process of change, during training

3.3.1 To Know "What You Are?"

The question could be answered in a variety of ways. One of the ways commonly followed is the attempt to reflect oneself keeping in view the image of an achievement-oriented person. In such a situation it is possible to visualize an "ideal self"; against the "real self" i.e. what is reality or the real image? The gap between the ideal self & the real self sets the Process of change in motion. It is possible to realize the gap and enhance willingness to fill up the gap through action. For example, Raju's real self is that he hates math's, but the ideal self is that he wants to become a Chartered Accountant. Now it is for Raju to fill this gap by taking steps.

Let us examine the steps:

- Reviewing one's failures and successes, fears and aspirations.
- Looking at the relation between one's own desires and what society. (Family & Culture) expects.
- Examining one's characteristic modes of behaviour resulting from understanding, attitude, opinions and beliefs.
- Looking at the self through the eyes of others.
- Studying fantasies\dreams and the actual behaviour.
- Identifying the internal potentialities.

3.3.2 To Know Your Destination

Once you know or discover the discrepancy between the ideal and real self it may create enough anxiety or discontentment and you may soon desire to change towards the ideal. This is important, as through discontentment, you may like to find alternative solutions. For this the following aspects may be kept in mind.

- Explore alternate ways of thinking and action and collecting factual information in relation to the consequences of these choices.
- Ensure quick feedback concerning the new Behavioural patterns and understand their significance.
- Evaluate progress in the desired direction.
- Try out the new Behavioural pattern in the real world outside the training experience.

3.3.3 To Believe that You Are The Master of Your Own Destiny

Fundamental to all the other conditions for change is growing conviction in you that you can change, take control and direct your own life. There are different ways through which any person can realize how powerful he is, rather than a pawn being pushed around by others. Try this simple strategy to bring about:

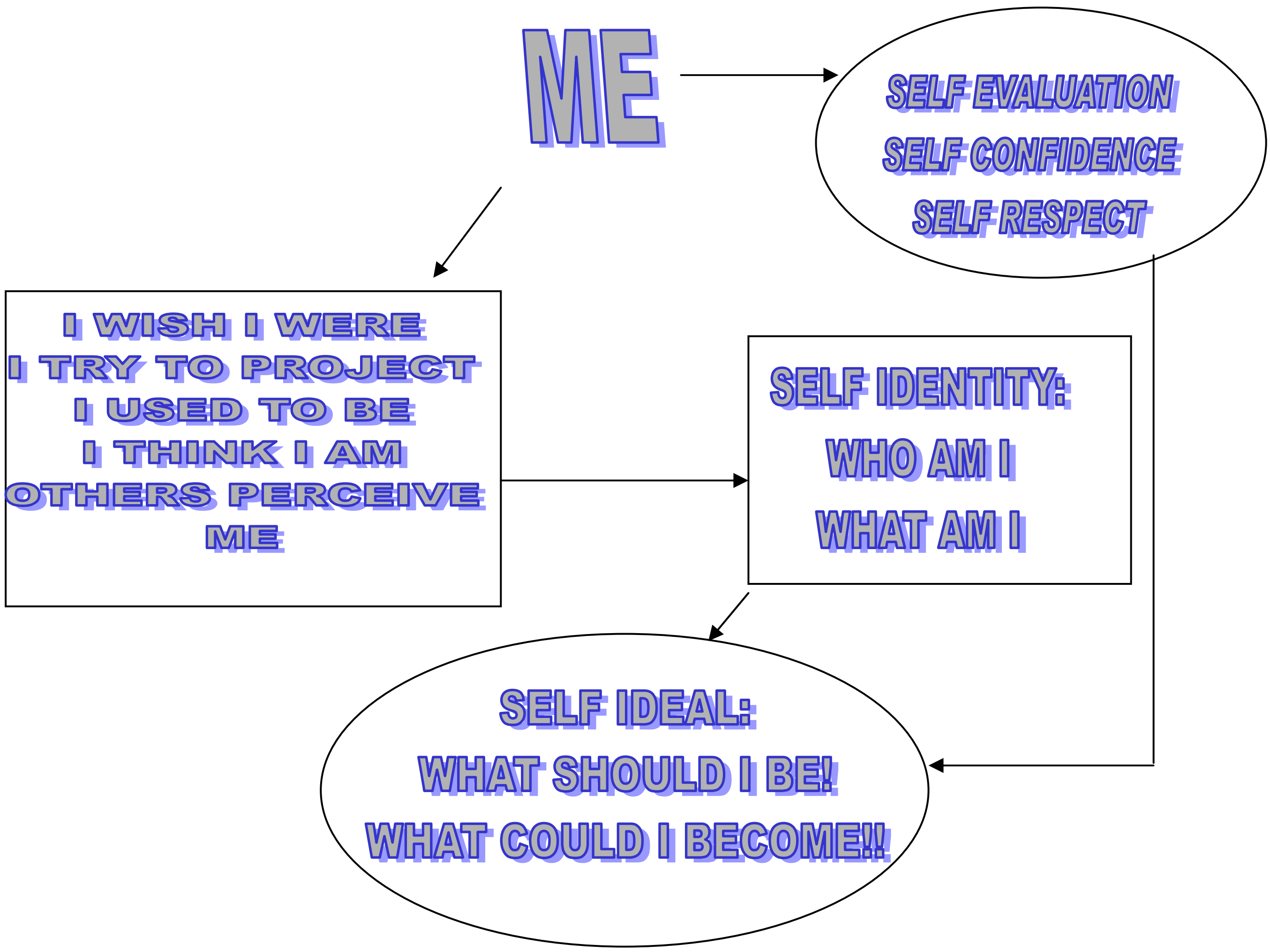
- Have belief in your capacity to help others and to learn from others.
- Have a constant desire to strive for change.
- Take a decision regarding pursing any change on your own rather than following prescription by others.

These will facilitate your thinking and help you towards building an entrepreneurial profile. Any desirable change in thinking will lead towards actions conducive to entrepreneurial performance.

3.3.4 To Develop a Positive Self Image

In order to develop an image of self, let us look at this diagram. The central focus is **'ME'**. This 'ME' is formed on what I think about myself, what I wish to become, how others perceive me and most important how I project myself. Based on this, I develop my own identity of "Who I am". However, this ME constantly goes through a continuous self-evaluation, which contributes to self-confidence and self-respect. Based on this evaluation the "Ideal self" is formed which helps the person to move forward towards the goal.

Remember this can make a person more focused. This leads to self-effectiveness and increased internal power or control.



Research has shown that a person desiring to be an entrepreneur has a goal where he is continuously engaged in some activity rather than just aiming at a goal where there is a lack of clarity. Further it has been found that such persons have tendency to solve rather than avoiding problems. They possess internal resources in the form of confidence, ability, capacity etc. rather than depending upon external resources or have a feeling of lack of resources. Similarly they are found to take initiative rather than wait for a direction from others to do the task. A content analysis of the essay on "Who I am?" can help in understanding and developing this concept.

3.4 LOCUS OF CONTROL

What is Locus of Control?

It means that the factors responsible for any event or an outcome of any action. The responsibility may be of external factor or internal factor. The internal factor may be under one's control but the external factor is not within one's control.

Let us take an example, Ravi has not scored well in his 10th Board exam. This is an event. Now for Ravi, he may justify the outcome in three ways

a) The paper was tough
b) I did not prepare properly for the exam
c) My luck was bad

For the response (a) and (c) the locus of control is **external** and for response (b) the locus of control is **internal**.

The persons who are more internal are more effective in whatever they do in their lives. They perform better than others as they believe in their own potential.

3.4.1 Effort, Performance and Outcomes

Let us try to understand the diagram further:

The relationship between self-effectiveness and locus of control and their effect on performance may be best summed up in the following diagram:

Effort (E) leads to performance (P), which then leads to outcome (O). An individual's belief that if they exert effort they will succeed, is their self-efficacy. Locus of control on the other hand, is their belief that they can perform in such a way as to achieve the desired outcome

$$E \xrightarrow[\text{Efficacy expectation (Self-efficacy)}]{\text{Leads to}} P \xrightarrow[\text{Outcome expectation (Locus of Control)}]{\text{Leads to}} O$$

It is possible to assess one's self-efficacy and plan for necessary changes if required. A simple task of writing an essay about "who I am" brings out significant dimensions, which are as follows: -

- Goal Setting
- Tendency to solve problem
- Locus of resources
- Source of initiation

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

LOCUS OF CONTROL - THE ENTREPRENEURIAL ORIENTATION INVENTORY*

Instructions: This Inventory contains twenty pairs of statements. In each pair, you may agree with one statement more than the other. You have five points to distribute between the two statements in each pair, to indicate the extent to which you agree with each of the statements. You may distribute the five points in any combination (0-5, 1-4, 2-3, 3-2, 4-1, 5-0). If you agree slightly more with statement "a" than with "b", then assign three points to "a" and two points to "b". If you agree completely with "a" but do not agree at all with "b", assign five points to "a" and zero to "b".

You may not divide your points equally (i.e., 2.5) between the two choices. You must choose one statement with which you agree more and then distribute the points.

		Points
1.	a) How successful an entrepreneur will be depends on a number of factors. One's capabilities may have very little to do with one's success.	....
	b) A capable entrepreneur can always shape his or her own destiny.	....
2.	a) Entrepreneurs are born, not made.	....
	b) It is possible for people to learn to become more enterprising even if they do not start out that way.	....
3.	a) Whether or not a salesperson will be able to sell his or her product depends on how effective the competitors are.	....
	b) No matter how good the competitors are, an effective salesperson always will be able to sell his or her product.	....
4.	a) Capable entrepreneurs believe in planning, their activities in advance.	....
	b) There is no need for advance planning, because no matter how enterprising one is, there always will be chance factors that influence success.	....

5. a) Whether or not a person can become a successful entrepreneur depends on social and economic conditions. ……….

   b) Real entrepreneurs can always be successful, irrespective of social and economic conditions. ………..

6. a) Entrepreneurs fail because of their own lack of ability and perceptiveness. ……….

   b) Entrepreneurs are bound to fail at least half the time, because success or failure depends on a number of factors beyond their control. ……….

7. a) Entrepreneurs are often victims of forces they can neither understand nor control. ……….

   b) By taking an active part in economic, social and political affairs, entrepreneurs can control events that affect their businesses. ……….

8. a) Whether or not you get a business loan depends on how fair the bank officer you deal with is. ……….

   b) Whether or not you get a business loan depends on how good your project plan is. ………..

9. a) When purchasing raw materials or any other goods, it is wise to collect as much information as possible from various sources and then to make a final choice ……….

   b) There is no point in collecting a lot of information; in the long run, the more you pay, the better the product is ……….

10. a) Whether or not you make profit in business depends on how lucky you are. ……….

    b) Whether or not you make a profit in business depends on how capable you are as an entrepreneur. ……….

11. a) Some types of people can never be successful as entrepreneurs. ……….

    b) It is possible to develop entrepreneurial ability in different types of people. ……….

12. a) Whether or not you will be a successful entrepreneur, depends on the social environment into which you were born. ……….

    b) People can become successful entrepreneurs with effort and capability irrespective of the social strata from which they originated. ……….

13. a) These days, people must depend at every point on the help, support, or mercy of others (governmental agencies, bureaucracies, banks, etc.) ....

b) It is possible to generate one's own income without depending too much on the bureaucracy. What is required is a knack in dealing with people. ....

14. a) The market situation today is very unpredictable. even perceptive entrepreneurs falter quite often. ....

b) When an entrepreneurs' prediction of the market situation is wrong, that person can blame only himself or herself for failing to read the market correctly. ....

15. a) With effort, people can determine their own destinies. ....

b) There is no point in spending time planning or doing things to change one's destiny. What is going to happen will happen. ....

16. a) There are many events beyond the control of entrepreneurs. ....

b) Entrepreneurs are the creators of their own experiences. ....

17. a) No matter now hard a person works, he or she will achieve only what is destined. ....

b) The rewards one achieves depend solely on the effort one makes. ....

18. a) Organizational effectiveness can be achieved by employing competent and effective people. ....

b) No matter how competent the employees in a company are, if socio-economic conditions are not good, the organization will have problems. ....

19. a) Leaving things to chance and letting time take care of them helps a person to relax and enjoy life. ....

b) Working for things always turns out better than leaving things to chance. ....

20. a) The work of competent people always will be recognized. ....

b) No matter how competent one is, it is almost impossible to get ahead in life without contacts. ....

3.5 ACHIEVEMENT MOTIVATION

Motive

The basic question 'What is Motive?' has to be answered and understood before we discuss the various motives characterizing human behaviour and development. To put it in simple language, 'motives' can be defined as various psychological needs in varying degrees of strength which are reflected in the continuous concerns an individual has, and his thoughts as occupied with such concerns.

What is important for you as an entrepreneur is one motive and that is the motive for achievement. Achievement motivation can be described as 'an urge in an individual to do something new, unique, an urge to excel in what he/she does and a long term involvement'. Before you move on you must understand that achievement motivation is necessary.

Though we are mainly concerned here with achievement motivation as related to entrepreneurship, we feel that you should know something about the sources of development of achievement motivation. They are:

Literature

As children, whatever we see, hear or read, influences us and our life. And when we grow up, our motivation depends on what we were exposed to in childhood. If we have been exposed to literature in any form which instills in us a desire to be independent, we exhibit a motivation to take our own decisions, to do something worthwhile in life, to have a goal, be an achiever. And this is further reinforced by what we read, see or hear, as well as our environment, as adults. To quote an example of a country, Japan, after its crushing defeat in the Second World War bounced back to become a rich and highly industrialized country. The reason was the literature which reflected the values of hard work and achievement in life.

Research in the field has shown that achievement motivation, as found in stories, newspapers and folk tales was reflected in the wealth or economy of a country and if and when it was not, the country started declining.

Child-Rearing

The way a child is brought up or reared, making him/her 'achievement-oriented', is also important, not only for the child but also for the community and country in general.

This early orientation, making a child independent in his/her thinking, involving him/her in decision-making at home and rearing him/her to take risks on his/her own, makes the child an achiever in life, thus influencing the country as a whole.

Here in our country we have street children who have to fend for themselves, which results in their becoming independent and develops in them the quality of decision-making.

As we have discussed in earlier units about the traits and qualities of an entrepreneur, achievement motivation is highly relevant to entrepreneurship. If you have achievement motivation of a certain degree, if you have a spark, it can be developed to make you a successful achiever, entrepreneur. But one word of caution: having high achievement motivation alone may not be sufficient to make you a successful entrepreneur. There are certain other requirements too, which you will know about as you read on.

Achievement Motivation and Internality

The 'Internal Locus of Control' refers to the belief that whatever happens to you is to a large extent, caused by you and that you have control over the outcome of your actions. This does not mean that the external environment does not influence the outcome of your efforts. But you should believe that ultimately success or failure depends on how you are able to do certain things and the awareness that you can intervene to influence the outcome of external factors. In order to possess such an attitude, you should identify your strengths, concentrate on them and be confident of using the same to influence the outcome.

Developing Achievement Motivation

'Suppose I do not have achievement motivation, can I develop it?' Yes, you can. There is a specialized training programme called 'Achievement Motivation Training' which is based on experiential learning. The other alternative is introspection and an analysis of your strengths, weaknesses, opportunities and threats (SWOT). After going through the chapters on entrepreneurial traits and competencies, based on self-learning you can try to improve yourself in the areas where you find yourself weak, and convert the weaknesses to strengths. Achievement motivation can also be developed by thinking in the language of achievement. Your entire thought process (imagery) has to be achievement oriented.

3.6 ACHIEVEMENT PLANNING AND BUSINESS GOAL

One of the most crucial skills for an entrepreneur is to plan and implement action towards business goal. Why is this important? Let us examine.

Through planning, you will be able to clearly specify your goals, identify various activities, anticipate obstacles, enlist resources and also anticipate consequences. Often people having no patience for planning, jump to work and get stuck when faced with obstacles. Therefore, to be a successful entrepreneur, you need to develop skill and insight in planning and firm faith that planning is a must to ensure success in accomplishing goal.

Entrepreneurs always set challenging goals, which are realized with difficulty but bear unique fruits. They are often governed by achievement motivation, which has concern to attain certain standard of excellence. For this reason the planning practised by entrepreneurs are often called 'achievement planning'. This should not be mistaken for project planning. *Achievement planning provides for the necessary psychological preparation of the entrepreneur to pay adequate attention to those significant dimensions of his/her action areas, which contribute to his/her eventual effectiveness.*

Let us understand how planning can be effective from this case study.

CASE STUDY

Jhora Medhi (34) a shy, homely lady decided to enter the field of entrepreneurship. She belongs to a family where service is the main occupation. After completing her HSLC, she discontinued her study and got married. She always wanted to do something to be financially self-dependent. After her marriage she felt that she had to supplement her husband's income for the economic well being of her family. She could do this by starting some income generating activity in her home itself. She observed that varieties of fruits were available in her locality. But fruits get wasted most often during the harvesting season. She had a hobby of making jams, jelly, pickle etc. for use in her own home. She felt that she could convert her hobby into a profitable source of income generation. She discussed her idea with her husband. Her husband also liked the idea of doing something to generate additional income. She started to make jams, jelly, and pickle and sold them to her friends and relatives. The products were good. Her friends and relatives began to appreciate them. This encouraged her further to continue her effort to make jams, jelly etc. In the meantime IIE organized an EDP at Nagaon. She came to know about the programme and wanted to participate in it. She was admitted in the training. The training gave her further confidence to convert her income generating activity into an entrepreneurial activity. But to do so, she needed money, machines, manpower etc. She could approach bank for loan. But she was not certain if she could get a loan from bank. For machines she could not depend on the local market.

In addition, she also needed to know the formalities for starting a food processing unit. But money was the most important resource for her to start her enterprise. She thought it worthwhile to start her enterprise on her own without any finance from bank. She had about Rs. 20,000/- in her savings account. With this initial investment of Rs. 20,000/- she started a fruit processing unit at Nagaon. This small amount of money was inadequate to run her unit. She then approached her friends and relatives to get money for running her unit. The problem of finance and machine could be solved. Now there was the problem of marketing. It is now not an income generating activity for her. It was an entrepreneurial activity.

She had to be able to market her products not only in the local market but also the outside market. She employed two salesmen to sell her products. The salesmen used to travel from place to place to sell the products. They took the products to different places in the morning and returned in the evening. In this way she could get the market of central Assam. Jhorna also used to travel to different towns and villages at regular intervals to establish contact with the sellers to sell her product. This helped her a lot in popularizing her products. In addition, she also used to put up advertisements to create awareness of her food processing unit and the quality of her product. Now there are ten persons working in her unit. Initially she faced the problem of getting FPO licence. She had to take a lot of trouble to overcome the problem. Her annual turnover during 1999 – 2000 was about Rs. 2 lakh.

What is the secret of her success in her entrepreneurial activity? She stated that hard work, foresight and planning are the major contributing factors in the success of her enterprise. Establishing linkage with market and her strong determination to be a successful entrepreneur contributed to her success.

*(**Source:** Women Entrepreneurs in India, Published by NISIET, Hyderabad 2002)*

We have understood from the case how planning is important for setting up an enterprise. However, planning also requires systematic analysis and careful implementation. In other words, planning is also known as the "blue print for the entrepreneur. Let us look at the various steps of planning.

3.6.1 How to Plan

The planning has to have some strategies. In order to achieve the desired goal, it involves nine steps:

- Analysis of Situation
- Goal Setting
- Enlisting Activities
- Anticipation of Potential Obstacles
- Location of resources
- Generating alternatives
- Anticipation of consequences
- Action Planning, and
- Feedback.

We will try to understand each of these one by one

Analysis of situation: Entrepreneurs analyze situation to perceive the emerging change and the problems that people will be facing to adjust to such changes. Such problem areas offer you the entrepreneurial/business opportunities.

Goal setting: Look for new ideas, product or services that people need. Use creativity and be innovative in setting challenging goal. Efforts should be made to make the goal crystal clear.

Enlisting activities: Being action oriented you as an entrepreneur will enlist activities needed to move towards goal.

Anticipation of possible obstacles: Every action is resisted. Entrepreneurs anticipate such barriers, which may arise within entrepreneurs themselves or in the environment.

Location of resources/help: If barrier exists then there must be some source/help somewhere to overcome it. You need to locate them.

Generate alternatives: Using the resource new activities are generated as alternatives.

Anticipate consequences: Before actual operation an entrepreneur anticipates the consequence based on previous experience and information.

Action planning: Action planning is a device meant to help the entrepreneur to crystallize the short tem and intermediate goals; and to visualize corresponding actions which, in his\her view, will ensure the movement towards the goals.

ASSIGNMENT-1

If you want to make a good plan of action, you should be able to answer questions such as:

- What action is to be taken?
- Why must it be done?
- Where will it take place?
- Who will do it?
- How will it be done? and
- How much control (kind and degree) should be exercised.

See if you can respond to all the questions at one attempt. find out which question is taking longer than others. Perhaps then you have to spend a little more time. Remember there are no right or wrong answers. What is more important is your clarity and focus. Try this after six months and you will see the difference in your response.

3.6.2 Feedback

Feedback is essential feature of achievement planning. An entrepreneur seeks feedback and uses it to effect change in the course of action to ensure accomplishment of goal.

3.6.3 Planning a Habit

Make it a habit to clearly set goal and plan its accomplishment by stating activities, possible obstacles, resources to overcome barriers and suggesting alternatives. This will ensure you success in your entire venture.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

Fill up the gap with appropriate words that you have learnt through these units.

Do match answers given at the end of the unit after you have completed.

1. Entrepreneurship is concerned with ----------- and putting it into social use against pay off.

2. ---------------- is used by entrepreneur to make innovation available to users/people.

3. Entrepreneurship contributes directly to national economy by increasing -------------- and --.

4. Entrepreneurship brings about changes in people's orientation towards solving ----------------- Taking ------------------ enhancing concern for ---------------.

5. Entrepreneurial opportunities are sensed by scanning the ---------------.

6. For selecting an enterprise, entrepreneurs consider its suitability to three Es including Entrepreneur, E------------ and E----------------.

7. Entrepreneur works for --------------- and accordingly believes in -------- before action.

8. Entrepreneurs perceive ---------------- faster than common persons.

9. Through planning entrepreneurs assess ---------------- required, quantity of -------------- to be produced, and ----------------------- where products/services are to be sold and the total ------------- that has to be made and finally the -------------- that is expected.

10. A business plan is the -------- ------------ ready with entrepreneur before actually launching a project.

ASSIGNMENT-2

(Achievement Planning and Business Goal)

Do this exercise on your own:

Identify an important task that you are required to complete by a specific date in the future.

1. Think about the task(goal).

2. Clearly state the goal. (Why you want to this?)

3. List out the activities needed to accomplish your goal.

4. List the problems you may face or which may arise in the "environment."

5. Suggest possible sources of help (from friends/parents\teachers} to overcome obstacles.

6. What are your chances of success or failure (indicate in%}.

7. Suggest alternative plans of action.

8. Draw plan of action.

3.7 LET US SUM UP

Developing entrepreneurial skills in us is possible. It requires right mindset to develop a strategy. Understanding oneself, own goal in life and identifying strengths and weaknesses are very crucial.

The locus of control both internal and external are important. In any task when we put our efforts, it leads to performance and further leads to outcome. Thus believing in one's own self-efficacy and ability is crucial. The recognition of external locus of control can help to develop the tendency to solve problems, taking help and openness to feedback for improvement.

However in order to achieve success we must plan for success. We must follow the steps in planning. Let us remember that in planning, anticipation and alternative plan of action is important.

3.8 KEY WORDS

Locus of control : Factors responsible for any event or an outcome for any action. The responsibility may be external factor or internal factor. The internal factor may be under one's control and the external factor is not within one's control.

Self-efficacy : Utilising one's own full potential for performance.

Achievement planning : necessary psychological preparation of the entrepreneur to pay adequate attention to those significant dimensions of his/her action areas, which contribute to his/her eventual effectiveness.

Acquisition : A recently acquired asset or object, the act of acquiring.

Accomplishing : Achieving or completing successfully.

Accomplishment : Something that has been achieved successfully, an activity. That one can do well.

Anticipate : Be aware of and take action regarding something likely to come about in the future.

Blue Print : A design plan or other technical drawing. Something which acts as a plan, model

Conducive : Contributing or helping towards.

Crystallize : Form or cause to form crystals, make or become definite and clear.

Discrepancy : An illogical or lack of compatibility.

Discontentment : Lack of satisfaction.

Enhance : Increase

Loci : Particular point or place.

Perceive : Become aware of or conscious of.

Recognition : Knowing again.

Visualize : Form a mental image.

3.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

(The Entrepreneurial Orientation Inventory Scoring Sheet)

Name --- Date -----------------------------

Instructions: Transfer your point allocations from the inventory form onto this scoring sheet.

Internal Locus of Control	External Locus of Control
1 b --------------	1 a --------------
2 b --------------	2 a --------------
3 b --------------	3 a --------------
4 a --------------	4 b --------------
5 b --------------	5 a --------------
6 a --------------	6 b --------------
7 b --------------	7 a --------------
8 b --------------	8 a --------------
9 a --------------	9 b --------------
10 b ------------	10 a ------------
11 b ------------	11 a ------------
12 b ------------	12 a ------------
13 b ------------	13 a ------------
14 b ------------	14 a ------------
15 a ------------	15 b ------------
16 b ------------	16 a ------------

17 b -------------	17 a -------------
18 a -------------	18 b -------------
19 b -------------	19 a -------------
20 a -------------	20 b -------------
Total Internal ------------------	Total External -----------------

Determine the ratios of your internal/external locus of control scores by dividing the total internal score by the total external score. Record the amount here -------

Internal/external ratios above 3.0 indicate a high level of entrepreneurial internality; the chances are high that such individuals will initiate entrepreneurial activities. Ratios below 1.0 indicate that the respondent has a more external (less entrepreneurial) locus-of-control orientation. There is a need for this type of person to become more internal in order to be able to initiate and sustain entrepreneurial activities. Ratios above 1.0 indicate possible entrepreneurs. The higher the ratios above 1.0, the more internal the respondent is.

* Test developed by T.V. Rao. Reproduced from the 1985 Annual, “Developing Human Resources”, Leonard D. Goodstein and J. William Pleiffer Edition. San Diego, California University Associates.

Check Your Progress Exercise 2

1. Innovation
2. Enterprise or Venture
3. GDP or GNP, and --- employment opportunity
4. Problems, -- Risk, --- Excellence
5. Environment
6. Enterprise, --- Environment (reverse also)
7. Success, --- Planning
8. Resources
9. Resources, -- Product, , --Places
   investment, --- Profit
10. Blue print

3.10 SOME USEFUL BOOKS

1. Akhouri, Mishra and Sengupta. R. (1999) Trainers Manual on Developing Entrepreneurial Motivation Published by NIESBUD.

2. C.B.S.E. (2002) “Entrepreneurship Class XI & XII”.

3. Gupta, C.B. (1992) Entrepreneurial Development, Sultan Chand & Sons.

4. Raju, U.B. and Rani, C. (Ed.) (2002) Women Entrepreneurs in India, Published.

5. Raymond, W.Y. Kao Tan Wee Liang (2001) Entrepreneurship and Enterprise Development in Asia, Prentice Hall.

UNIT 4 BUSINESS IDEA – HOW TO GET IT?

Structure

4.0 OBJECTIVES

After studying this unit, you should be able to:

- make a distinction between economic and non-economic activities;
- understand the meaning and nature of business;
- identify various business opportunities, which a businessman may come across;
- describe the various sources from which a businessman may derive business ideas;
- understand as to how to generate the business ideas; and
- comprehend the evaluation procedure of a business idea.

4.1 INTRODUCTION

All of us are always engaged in some activity or the other. In the morning when we get up we brush our teeth, take bath, offer prayers and have our breakfast. Then, you as a student go to your Study Centre for studies. Your parents go about their own occupations. In the evening somebody may watch television or go for playing. The point, which needs to be stressed here is, that every human being is busy in some activity or the other.

A person may do a particular piece of work just to derive happiness or peace within himself. This is a non-economic activity. Another activity, may be to earn money. This is an economic activity. Business falls in the category of economic activity – the objective being to earn money.

A business can be started by any person. It can be pursued as a career by him. He may start a business with any amount of money. The range of investment may be as low as Rs. 100 or as high as Rs. 1,00,000 or even more depending upon how enterprising and courageous he is. But have you ever thought of the aspect which we all need the most to start a business? Well, it is the idea of – **What to Do?**

A businessman needs to decide upon the type of activity, which he will be interested in pursuing. Let's change your role for a moment. Visualize the following:

You have just completed the present Diploma Course. You want to start your own business. The pertinent question here is – which business you want to be involved in. Whether you want to manufacture something or simply want to start a trading business. Are you in a dilemma? If the answer is yes, here is a hint for you.

Look around yourself and try to identify an opportunity. May be you get your answer by keenly observing the environment i.e. consumers, producers, products, competitors, government, society etc. Well, this is exactly what a businessman does.

The businessman starts the initial work of identifying various business opportunities, which he may come across. He then evaluates these opportunities and gives a shape to his business idea.

4.2 WHAT IS BUSINESS?

In this Unit we shall discuss about business, business opportunities, business ideas and other related aspects.

As already mentioned, business is an economic activity. The objective of doing any business is to earn profit. Business involves a wide range of activities like manufacturing, trading, transportation, warehousing etc.

Definitions of business

1. *According to B.O. Wheeler:* "Business is an institution organized and operated to provide goods and services to society under the incentive of private gain."

2. *As per Section 2 (13) of the Income Tax Act, 1961:* "Business is any trade, commerce or manufacture or any venture in the nature of trade, commerce or manufacture."

Features of business

Let's discuss the features of business one by one

1. *Economic activity*

   Business is an economic activity because it involves production, exchange and distribution of goods and services for profit, e.g. Arun sells goods worth Rs. 1,000 to Bhanu for Rs. 1,200 – it is a case of business activity. In case Arun donates Rs. 11 to a temple it is not a business activity.

2. *Profit motive*

   The main aim of a businessman is to earn profit. If a businessman is manufacturing cloth or is dealing in purchase or sale of wheat – the main reason behind this activity is some kind of gain or reward.

3. *Goods or services*

   A businessman deals in goods or provides services.

The *goods* in which he may deal are of two types:

(i) Consumer Goods;
(ii) Producer Goods

Consumer goods are those goods, which are used by consumers to satisfy their needs and wants directly. In this case goods are used or consumed after their purchase. The examples are – bread, milk, cloth, pulses, furniture etc.

Producer goods, also known as capital goods, are those goods, which help in the manufacture of consumer goods. These goods are used by manufacturers and not consumers. Examples are – tools and equipment, machinery boilers, wheat used as seeds for further growing, etc.

The *services* in which a businessman may deal in, can be grouped as below:

- Transport
- Warehousing
- Advertising
- Marketing
- Banking
- Insurance

4. *Production of goods and services*

A businessman endows utility to a material by making it more useful and suitable. A businessman can satisfy human wants only if he makes something useful e.g. cotton as such is of no use to consumers. But if the same cotton is converted into cloth by a manufacturer, the needs and wants of the customers are satisfied. This way, the businessman by manufacturing, processing or altering the material creates 'form utility' to make the product more useful.

5. *Distribution of goods and services*

Have you ever thought of how wheat cultivated by the farmer reaches the final consumer i.e. you and your family and others in society? Well, it is due to the distribution function of trade. Distribution of goods and services is a function, which facilitates the flow of goods and services from the manufacturer to the ultimate consumer.

6. *Risk*

Every kind of business involves risk – whether small or big, whether manufacturing or selling, whether done in rural areas or urban areas.

A business involves risk due to uncertain factors. The businessman does not have full control over his environment e.g.:

- The tastes and fashions may change;
- Level of competition may rise;
- Government policies, commercial, fiscal etc. may change in the country;
- Technology of production may change;

There is a direct relationship between the risk and profit. Higher the risk, higher the profit. In a way, profit is the reward for risk-bearing. Profit is termed as the compensation for risk undertaken by the businessman.

7. *Sale, transfer and exchange*

   Buying, selling and exchange of goods and services are the essential features of any business. Sale and exchange for a price is a must if the activity is to be considered as a business activity.

Forms of business activities

Business activities, *inter-alia*, may take the following forms:

- Agricultural activities – growing of crops, preparing harvest for the market, preservation etc.
- Manufacturing activities – manufacture of pickles, jams, papads, biscuits, chutneys, spices, sauces, pump sets, agricultural implements, spare parts etc.
- Trading activities – buying and selling in wholesale, retail or barter
- Service activities – transportation, warehousing, insurance etc.
- Reproducing and multiplying activities – nurseries which multiply and sell plants, plant materials
- Mining activities – exploration, extraction of minerals, iron ores, gold, diamonds etc.
- Constructing activities – construction of buildings, warehouses, cold storages, silos, etc.

4.3 BUSINESS OPPORTUNITY – IDENTIFICATION AND ASSESSMENT

Business opportunity identification

Let’s begin with identifying various business opportunities.

As we are all aware one should know how to swim before plunging into the water or else the person will get drowned. Same is the case with a person who wishes to start a business of his own he should acquire necessary knowledge. Even when he thinks of expanding his existing business, he has to update his knowledge.

The process begins with an effort to think out an attractive set of opportunities for the firm. In case the firm has too many opportunities, the task will be to select from among them.

A businessman can choose an opportunity from his environment. As long as there are unsatisfied needs and wants, there will be opportunities. Identification of such opportunities requires imagination, sensitivity and realistic assessment of what a businessman can do. For example, in the modern world the need to develop new sources of energy, to improve agricultural methods etc.

By going through the following examples, you'll understand more will throw up many possibilities clearly how a businessman can identify business opportunities.

Example I

Nanak discovers that there is no wholesaler dealing in sugar in his area. Nanak sees an opportunity in becoming wholesaler himself.

Example II

Rakesh, a student living in Shahibabad, is undergoing a Diploma Course on Value Added Products from Fruits and Vegetables conducted by IGNOU. One of his cousins Amar works as a gardener in AIIMS in New Delhi. Casually Amar discloses to Rakesh that affluent families in Delhi living in big bungalows maintain a kitchen garden in their courtyards but they find difficulty in obtaining seeds of good quality of various fruits and vegetables, green/flowering plants and high quality manure. Here, Rakesh is face-to-face with a business opportunity of selling good quality seeds (even imported ones), green/flowering plants and manure in Delhi and nearby areas. He can also act as Garden and Landscape consultant.

Example III

A commercial bank announces a loan scheme under which loan can be obtained for business purposes at a reasonably low rate of interest. The loan can be repaid in easy installments. Ravi, a money-starved young businessman who owns a juice shop reads about the loan scheme on a visit to a branch of that bank. He has identified an opportunity for expanding his juice shop.

Activity

Scan your environment thoroughly. Think. And then identify five business opportunities and list them in a serial order in the space provided below:

Sl. No.	Business opportunity identification
1.	
2.	
3.	
4.	
5.	

Opportunity assessment

After the businessman has identified various opportunities, the next step is to evaluate these opportunities. The opportunities need to be assessed before the best one is transformed into a business idea.

Let's now study the procedure of assessing an opportunity, which has been identified.

i) *To choose the relevant opportunities*

The businessman has to make a choice of the relevant opportunities out of the various opportunities available in the environment. Certain opportunities (and not all) will be relevant only if they meet the purpose, objectives and growth strategies of the firm.

For example, Darshan Kumar, a manufacturer of vegetable sauce, finds that the Finance Minister has announced slashing of excise duty on steel. This is an opportunity, which a businessman may find to be quite useful but it has no relevance to Darshan Kumar because he is in the business of manufacturing vegetable sauce using various vegetables and not steel.

In other words, business opportunities should be consistent with the purpose and objectives of the firm.

ii) *To evaluate the sales potential of each opportunity*

After identifying the available relevant opportunity, the businessman should evaluate the sales potential of each opportunity. In this context, following questions need to be considered:

a) Who would buy the product;

b) How much the potential customers can pay;

c) How many customers would buy the product;

d) Which strata of society would buy the product;

e) Who will be the competitors;

f) How would the product be distributed.

iii) *To evaluate the financial aspect of each opportunity*

Each identified opportunity is required to be evaluated in terms of financial aspects. This will lead to proper and detailed estimation of cost. The various items on which long-term funds can be committed are:

a) Cost of land and site development

b) Cost of building

c) Cost of plant and machinery

d) Money required for working capital

iv) *To evaluate the technical aspect of each opportunity*

Evaluation of each identified opportunity in terms of technical aspects is also an essential step. The various technical elements to be evaluated are:

a) Type of raw material to be used – agricultural product or livestock product or mineral product;

b) Manufacturing process;

c) Plant capacity required;

d) Technology for manufacturing – whether to purchase or make it available through *joint venture* arrangement.

e) Availability of infrastructure – power, transportation, water and communication.

v) *To evaluate the marketing aspect of each opportunity*

Each business opportunity should also be analyzed from the point of view of how to enter the market. The company should make an effort to know what its competitors are offering to the consumers and in which way can the consumers be satisfied.

The businessman should bank upon that opportunity which is most feasible and promising.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Read the following paragraph, identify the relevant business opportunity and fill your answer in the space provided.

   Manoj is a young enterprising man. He owns a sweet shop. He is well versed with Indian culture and festivals. He knows that on the occasion of various festivals people make different kind of sweets and namkeens. Here, he finds a good business opportunity to be turned into a viable business idea. He may ……………………………………………………………….

   ………………………………………………………………………………

2. You are Kailash Nath and you own a *chakki* shop. Through your customers, you come to know that packed masalas (i.e. packed spices) available in the market are not of good quality as they are thought to be adulterated. In the following space write down the relevant business opportunity, which you will identify.

   ………………………………………………………………………………

   ………………………………………………………………………………

   ………………………………………………………………………………

   ………………………………………………………………………………

4.4 SOURCES OF BUSINESS IDEA

Once an opportunity has been identified and assessed, the next step for a businessman is to translate the business opportunity into a viable business idea. In this respect the businessman has to seek the sources from where he can get his business idea so that the available opportunity is translated into a profitable venture.

A businessman should keep his mind open. According to Promod Batra, a management expert "A closed mind is like a gloomy cave made gloomier by the cobwebs of ignorance and prejudice, whereas an open mind is like a green meadow where fresh ideas spread and blossom. The businessman should therefore, step out of the morass of stagnant thoughts into the open field of bold new opportunities. He should soar high on the strength of an exploring mind to reach unknown heights of achievement and success."

The various *sources* from where a businessman can derive business ideas are presented in Figure 4.1.

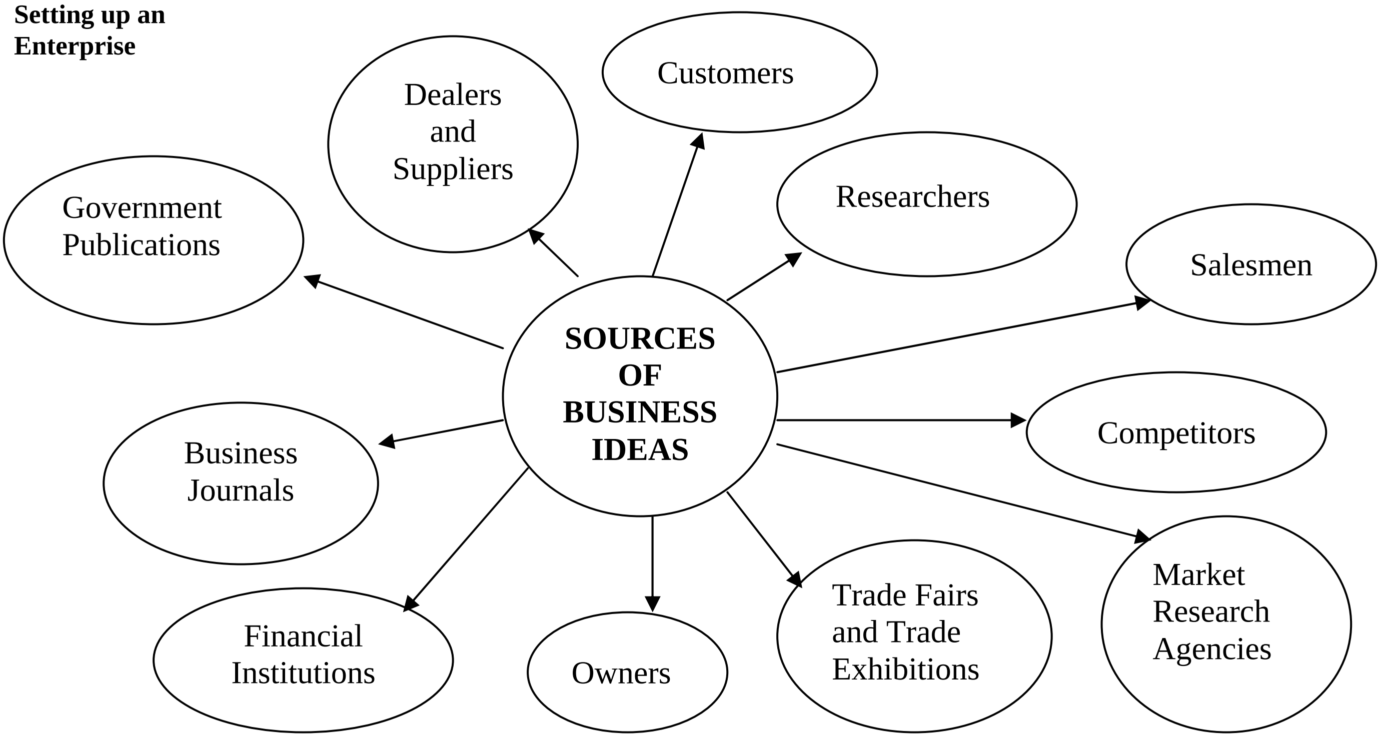


Figure 4.1: Diagrammatic presentation of sources of business idea

These are detailed in the following paragraphs.

1. *Customers*

Customers, whether Indians or foreigners, are the primary source of business idea. Customers, as we know, are the pivot around whom the entire marketing process revolves. Customers are those persons who use or consume the product and therefore, are the best judge. The ideas or the criticism provided by these esteemed customers are valued greatly by the business firms. The business unit can identify customers' needs and wants through surveys, group discussions, suggestion system etc.

2. *Researchers*

Researchers are those talented scientists, who because of their various scientific research programmes conducted in the labs, try to bring out something new – it can be a new product or modification of an existing product or a new form of packaging material. Big companies maintain R & D department for this purpose only. R & D labs carry out research and hence become a source of business idea.

3. *Competitors*

A businessman should never undermine his competitors. He should monitor the activities and strategies used by them carefully specially in connection with bringing out new products, new methods of selling, and new promotional measures. A businessman should try to add some value to their product and build a far better product than his rivals.

4. *Salesmen*

Salesmen or sales-managers or sales representatives – with whatever name we may call them – are the ones who come in direct contact with the final consumers. Whether it is a multi-national company (MNC) of Nestle or

Kellogg fame or a local chat-papri shop – the customers interact only with the salesmen while buying the product. In this process, the sales persons happen to get exposed to complaints and problems faced by the customers while using the product. They also come in contact with the unsatisfied needs of the customers as well. They can lead the owners of the business firms on to the right track. Therefore, they are a good source of business ideas.

5. *Owners*

The owner of an enterprise can be a single person or a group of persons depending upon the form of business ownership. They are also a major source of business ideas. They may have a creative and innovative mind churning out new ideas to take their enterprise to the top.

6. *Government publications*

Government Publications are also an important source of business ideas. Data, provided in various Government publications, act as a harbinger for business improvement. The scope of further investment can also be estimated. The various publications like Economic Surveys published by the Ministry of Finance, Guidelines to Industries published by the Department of Industries, Annual Reports of the various Ministries etc. provide information about structure, location, licensed and installed capacity etc. of various projects. Through analysing the available statistics regarding exports and imports a trend of foreign trade can be judged. Idea about import substitution can be generated by analysing the data of imports and possibility of exports can be estimated through export data.

7. *Business journals and financial newspapers*

Information regarding business idea can also be gathered from business journals, business bulletins, business magazines, financial newspapers etc. Some of these are:

- Indian Textile Bulletin
- Indian Packaging Directory
- Glass Udyog
- Glass Gazette
- Business India
- Business World
- Economic Times
- Financial Express
- RBI Bulletin

8. *Financial institutions*

Commercial banks, RRBs, State Co-operative Banks, State Financial Corporations, EXIM Bank, IDBI, SIDBI etc. are there to promote development of Industries, to conduct studies and to offer valuable suggestions to potential entrepreneurs.

9. *Market research agencies*

Market Research Agencies (MRAs) are also an important source of business ideas. These agencies conduct marketing research covering different segments of the market. They prepare research reports for their clients. Some of the MRAs are Indian Market Research Bureau (IMRB), Marketing and Research Group (MARG), Operations Research Group (ORG), National Council of Applied Economic Research (NCAER), Marketing Operations, Design and Enquiry Service (MODE), and Pathfinders India.

10. Trade fairs and trade exhibitions

Trade Fairs and Trade Exhibitions also contribute in searching for a business idea. Direct interaction takes place among the manufacturers, dealers, suppliers and customers through these fairs and exhibitions. National and International trade fairs provide an excellent opportunity to know about new products and development of existing products. A lot of information/data can be collected which may be used for evaluation purposes.

11. Dealers and suppliers

Business ideas given by Dealers and Suppliers are also an important source. Therefore, their viewpoint should also be considered because they have first hand exposure to customers' unsatisfied needs and complaints.

12. Performance of existing industries

The profitability and return on investments of various industries (region wise) are also one of the important sources for gathering business ideas. The potential for investments in the particular industry (e.g. fruits and vegetable processing industry) can thereby be analysed and judged.

Activity

In the following Table you will find unsatisfied needs and other problems of the customers as well as the relevant product to mitigate the problems. Scan the environment and fill in the Brand Name of the Product:

Customers' unsatisfied needs and problems	*Relevant product*	*Brand name of the product*
1. Heart Problem	Edible Oil	
2. Diabetes	Sugar Free Tablets	
3. Travelling	Sauce in sachets	
4. Hygiene	Water	

(**Hint:** 1. Saffola Gold, 2. Equal, 3. Kissan and 4. Bisleri)

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name two financial newspapers from which the businessman may get a business idea.

   i) ....

   ii) ....

2. Customers are an important source of business idea because:

....

....

....

4.5 GENERATION OF BUSINESS IDEA

Identification of business opportunity and its assessment leads the businessman to generate business ideas, which can translate the opportunity into a profitable venture.

Business idea can never come from a vacuum. Instead it originates from a creative and enthusiastic mind feeding on an active environment.

The process of identifying business idea should always be done in a systematic and rational way. It is always better "To think at leisure and never repent" and not "To act in haste and repent at leisure." That is why, the businessman should sensibly scan the environment, which consists of himself, his prospective customers who will buy from him, his prospective suppliers, his prospective competitors whom he has to face, etc.

The businessman can generate a business idea to sense a business opportunity in different ways. But before detailing them out let's go through some of the examples given below. These examples contain the opportunity and its transformation into a business idea.

Example 1

Business opportunity	Business idea generated
A cold storage is built in a village.	The businessman gets an idea to deal in off-season fruits and vegetables as well.

Example 2

Business opportunity	Business idea generated
Indian Railways starts a new train on a new route.	The businessman (dealing in flowers i.e. florist) gets an idea to expand his business by delivering the flowers through the new train to other areas, which were hitherto not tried.

Example 3

Business opportunity	Business idea generated
State Government announces the plan to provide free mid-day meals in primary schools in a village.	The businessman puts in efforts to take the contract of supplying vegetables to the contractor.

Figure 4.2: Diagrammatic presentation of generation of business idea

Now, let's discuss the generation of business idea.

1. ***Product imitation:*** The businessman can think of manufacturing any product, which already exists in the market. In other words the businessman may think of making a product, which already has a market. He wants to bank upon the efforts put in by his rivals. Product awareness and product acceptability are already there. Acquisition of an existing product obviates the costly and time-consuming process of building resources and reputation. For example, Suresh plans to manufacture instant Gulab Jamun mix. Here, Suresh is saved from putting in extra efforts and money to launch a totally new product as the customers are aware of this product and have accepted this mixture through which instant Gulab Jamun can be made.

2. ***Manufacturing of a new product (Product innovation):*** A businessman can plan to make a non-existing product, which is not available in the market. Well isn't it a big deal? Every businessman cannot do such an act. One needs to be extra bold, courageous, risk taker and adventurous, for it can be a risky proposition. Can you think of a new product, which has been recently launched in Indian food markets? Yes, there are products like Tomato Puree, Ginger-Garlic paste, instant cake mix etc. But there are

certain other new products also (though not linked with food industry) like mobile phones with camera, solar cookers, Jackets with in-built fans, etc. which were previously unheard of. Now-a-days some new types of namkeens like roasted wheat, roasted Kabuli (white) Chana, roasted moong dal etc. (cooked without using oil) have emerged in the market.

3. ***Manufacturing of an existing product but after adding more value to it or improving it:*** At times, a businessman thinks of manufacturing an existing product but with a difference. He tries to make that product slightly different from the product of his rivals by making some changes in the product. For example, 'Marie' biscuits are now in the market as 'Marie Gold' biscuits enriched with wheat fibre and with a slogan "better tastier and healthier". Some of the other examples are given below:

   - Pickles are sold with a new and better package;
   - Custard powder is now sold with some added ingredients;
   - Double Folding Umbrellas are an improvement over the single folded umbrellas in as much as they can easily be accommodated in ladies' purses;
   - Sauces, herbal shampoos are sold in sachets.

4. ***Manufacturing of a product after listening to the needs and wants of the customers:*** With liberalisation and globalisation processes, the entire environment is changing. The life and life style of people are changing. People, by and large, are buried neck deep in their responsibilities and duties, entrusted to them by their bosses so that they hardly get time for themselves and for their family. More and more women are working and they have less and less time for their family. In this changing life style, they want products tailor-made to suit their requirements. The businessman can therefore, find more ideas by asking customers to describe their problems with the current product. He can also identify customers' needs and wants through customer surveys, group discussion, suggestion system and letters received from them. The products, which have taken birth after listening to customers' woes, are:

   - Ready to eat food;
   - Ready to eat mushroom soup, tomato soup etc.;
   - Cake mix;
   - Sprouted Dals;
   - Roasted Namkeens;
   - Pudding Syrups.

5. ***Finding new uses for an old product***

   At times, the businessman may find some more and new uses of the product to increase his turnover. For example, 'Ready to Mix' product – a mixture of Badam-Pista flavour; of chocolate flavour; and of strawberry flavour, was launched for making milk shakes of different flavours. But, later on a number of uses were added the product could be used in ice creams, puddings, cakes etc.

6. ***Own problems and use of hobby:*** Sometimes, a person may face a particular problem in real life like preparing lunch for taking to office. He may, after leaving the job, start the business of supplying packed lunch during lunch-time at various offices. Recently, a fat lady was totally upset as she was not getting ready-made clothes of her size. She thought of this problem and started making over-sized clothes meant for fat people.

   A hobby can also be converted into a full-fledged business with proper planning and care. For example, a hobby of collecting flowers can be converted into making designer bouquets. Similarly, a hobby of making pickles and chutney can be converted into a Pickle and Jam business.

7. ***Untapped natural resources:*** Nature is very kind to mankind. It has given us plenty of resources like air, water, minerals, vegetation etc. Human beings satisfy their needs and wants through these natural resources. Here comes the role of a businessman. He can tap these natural resources and thereby satisfy the needs of the customers. For example, some of the products made through tapping solar energy are solar cookers, solar heaters etc.

8. ***Latest fashion and changing life styles:*** Latest fashions and designs and changing life-styles also contribute to the generation of business ideas. Nothing is permanent except change. Due to globalisation and liberalisation the common man especially the youngsters are a more aware and informed lot. The life-style of persons has also changed. An idea can be generated by observing keenly the latest fashions in the city. The businessman can therefore, make that product which goes well with the current market trend.

   Earlier pizza was not thought of as a common item to be consumed by all sorts of people. Similarly 'pasta' and other popular fast food items like 'momos', 'macaroni' etc. were also not in common use. But now-a-days, due to changing life styles, all these items are liked by the common man and their consumption is quite frequent.

9. ***Research and development programmes:*** Many business units hope to find new ideas through their scientific research programmes.

10. ***Consumption in foreign countries:*** Observing consumption in foreign countries may also lead to generation of new ideas. Each country has its own culture, and different food habits. In India we like spicy and fried foods while in western countries boiled, baked and non-vegetarian food is preferred. These consumption habits of people living in different countries may be used by the businessmen to generate an idea, which may suit the needs and wants of the people living in our country.

Activity

Let's do some fieldwork. Visit five houses in your neighbourhood. Ask the occupants, (women and children preferred) about any kind of improvement they would like to see in a particular product (fruit and vegetable products preferred) and fill the boxes given below:

Sl. No.	Name of the occupant	Age	Name of the product	Required improvement
1.				
2.				
3.				
4.				
5.				

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State True or False;

   i) Acquisition of an existing product obviates the costly and time-consuming process of building resources and reputation.

   ii) A businessman should never plan to make something new, as it will always result in losses.

   iii) The customers want customized products due to changing life-style.

   iv) The company can identify the needs and wants of the customers through surveys and discussions.

   v) Less business ideas are generated due to liberalisation and globalisation.

2. You are the manufacturer of "Delicious Biscuits (salted)". Think and write in the space provided below any two new uses of the product.

   i) ....

   ii) ....

4.6 EVALUATION OF BUSINESS IDEA

Consequent upon the generation of business idea, begins the important task of its evaluation. Before the businessman gives a green signal to his project, he has to do some spadework. He should critically analyse his business proposal in question. This becomes imperative, keeping in mind the money involved – may be his life time savings - the physical and human resources used by him, utilisation of natural resources which may involve environmental degradation etc.

A businessman would always wish to turn his dream project into a reality and not a nightmare. Let's now discuss the series of steps essential for any businessman to evaluate a business idea. These steps are as below:

1. *Evaluate one-self*

   The businessman should have certain personal qualities. These qualities will help him to survive in the market, face the competition, to diversify etc. The qualities, which are very essential for any businessman, are as follows:

   - Good health
   - Sound mind
   - Bold and confident spirit
   - Knowledge of skill to be used in business
   - Good interpersonal relations
   - Dynamic attitude
   - Innovative mind
   - Cautious nature etc.

2. *Collection of information*

   The next important step is to collect information about the environment in which the businessman plans to operate. The businessman may gather information directly. He may conduct surveys of the market and try to feel the pulse of the market and business methods of his rivals. He would assess the current tastes and fashions prevalent in society-motive for buying total demand, unsatisfied needs etc. Information can be collected through some other sources also like telephone directories, offices of Registrars of small-scale units, Census of India, RBI Bulletins, Journal of Indian Banks' Association, Economic Surveys etc.

   Market Surveys conducted by the businessman are a costly affair, whereas information collected from other sources may not be fully reliable, accurate, or comprehensive. Therefore, it must be carefully examined.

3. *Reviewing the limitations*

   Though an entrepreneur is bold in taking risks and facing challenges, he wants to make doubly sure and safe before he ventures into a new project. Therefore, he analyses those activities, which may act as hurdles at a later stage. His apprehension can be related to:

   - Availability of required amount of capital;
   - Availability of required land;
   - Availability of required skilled and unskilled workers
   - Strategies of the competitors etc.

4. *Detailed investigations*

   "Think before you leap" is what the wise men say. A wise businessman is one who puts each new step cautiously. Before finalizing his business proposal, he should investigate about the following points, which if left unattended may prove fatal to his business:

   - Investigation No. 1 (Capital Requirement)

     The businessman should assess his capital needs. He should analyse whether the capital requirements are within the manageable limits or not. He can obtain funds from the following sources:

i) His own savings;
ii) Friends and relatives;
iii) Commercial banks;
iv) Regional Rural Banks;
v) Co-operative Banks;
vi) Agricultural Co-operative Societies etc.

A businessman may require money as fixed capital and as working capital. Fixed capital is required to purchase fixed assets like building, plant, machinery etc. and working capital is required to finance day-to-day operations.

Activity

Baldeo plans to open a local bakery shop and make 'biscuits and other bakery items'. List the various items of expenditure for which he will be committing his capital as fixed capital and working capital:

Fixed capital required for	Working capital required for
1.	
2.	
3.	
4.	

(**Hint:** Fixed Capital required for – Small Building/Shed, Grinder, Vehicle, Furnace, Utensils. Working Capital required for – Expenses incurred for purchasing Raw Material like maida, sugar etc., Salary and wages to workers, Repair expenses of grinder, Monthly Rent to Landlord.)

- Investigation No. 2 (Location)

  Location refers to a fairly broad area. It can be a village, a local area, a city, an industrial zone or a coastal area. Site is a specific piece of land where the project will be set up. A manufacturer will decide about the location of site of his factory and a trader of his shop. The cost of production and saleability as well as profitability of the concern depend much on its location.

  A factory located far away from the place of availability of raw material or far away from the port town (in case of exports) will result in increasing the cost of production.

  The choice of location depends upon certain other aspects also like availability of infrastructure (e.g. power, transportation, water, communication system etc.), government policies, pollution control, climatic conditions etc.

- Investigation No. 3 (Sources of Raw Material)

  As per the needs of his business, the businessman shall require various raw material like cotton, jute, oil seeds, pulses, whole spices etc. The place from where raw material is to be obtained should also to be investigated. It is quite possible that prices of the required raw material may be different at different places. It may also happen that a particular dealer may offer some discount etc. Raw material can also be purchased from the wholesaler or directly from the producer. Transportation charges or delivery charges are also to be kept in view before finalizing the decision on the source of raw material. Quality of raw material is also to be considered. In addition, the question whether the dealer will be able to provide a regular supply of raw material – even when there is a shortage – should also be given full consideration.

  Raw material can also be imported from the country of its origin. In this respect cost of freight levy import duty and the time lag involved should be given due consideration.

- Investigation No. 4 (Sources of Labour)

  The businessman before starting his business needs to decide upon the place from where he would take his workforce. Recruitment of labour will depend upon the type of work, the businessman wants to start. He may require technical, skilled, semi-skilled, unskilled or highly educated workers depending upon the nature of work to be undertaken by him.

  He should enquire about the places from where he would get the right kind of labour. He should also look into the past trend in labour rates, prevailing labour rates, labour attitudes and practices etc.

- Investigation No. 5 (Availability of Technology)

  Choice of technology is an important factor for manufacturing a product. Choice of technology is influenced by many considerations like capacity of the plant, investment outlay, production cost, principal inputs, ease of absorption etc. In a nutshell, the technology should be such as has been proven to be successful by other manufacturers.

- Investigation No. 6 (Availability of Machinery)

  The requirement of machinery will depend upon the plant technology and plant capacity. The businessman will enquire from various manufacturers and dealers about the price, quality and other terms and conditions (e.g. warranty period, after sales service etc.) regarding the machinery to be purchased. He can also think of importing a particular machine, if required. The businessman will work out through cost-benefit analysis and decide accordingly. If he plans to buy machinery from a foreign party, then he should work out a detailed analysis of the proposal because the cost may escalate due to import duty, transportation, insurance etc. and the exporter may be unknown to him. The machinery purchased should be of desired quality and capacity and should be purchased from a reputed supplier.

- Investigation No. 7 (Availability of Adequate Power Supply)

  Supply situation of power, coal etc. needs to be thought of. The businessman needs to analyse whether power supply for his business proposal can reasonably be obtained from external sources? Whether he needs to install generator set. If yes, of how much capacity, etc. also the cost of the power.

5. *Consistency with government priorities*

   The idea must be feasible from the point of view of national goals and government regulatory framework. The entrepreneur should ask himself whether there would be any environmental effect contrary to government regulations, He should also visualise the foreign exchange requirement, if any.

6. *Cost reasonableness*

   The businessman has to take into account the cost of the project in hand. The cost structure should be such that it enables him to realize an acceptable profit with a competitive price. He should examine cost of material, labour cost, general administration cost, service cost, selling cost etc.

7. *Adequacy of the market*

   The businessman should analyse that the size of the present market must offer the prospects of adequate sales volume and a reasonable return on investment. Moreover, there should be potential for growth. He should analyse the total present domestic market, competitors and their market share, sales and distribution system, barriers to the entry of new units etc.

8. *Assessment of risks*

   The desirability of a project is critically dependent on the risk inherent in it. The businessman should analyse the threat from competitors, vulnerability to business cycles, competition from importers etc.

9. *Scale of operation*

   To decide the scale on which the business is to function is an important aspect that needs to be emphasized. The businessman can operate on small, medium or large scale depending upon his finances, abilities and entrepreneurship as also size of the market etc.

10. *Form of business ownership*

    The form of business ownership is yet another dimension which is to be thought upon before commencing the business. The important forms of business ownership are sole proprietorship, partnership, company (private or public), co-operative society etc.

11. *Compliance with legal formalities*

    The businessman should also evaluate the business in terms of legal formalities, which need to be fulfilled. A variety of licences, approvals, clearances etc. may be required to be obtained from the authorities depending upon the nature of business. Some of the examples are given in the following Table:

Nature of the business	Relevant authority
Packed Foods	Directorate of Marketing & Inspection, Ministry of Agriculture
Excisable Products	Central Excise Department
Bakery Items	Local Authority/Health Department
Confectionery Shop	Local Authority

Conclusion

After going through critically and analytically the various investigations and other relevant points related to the evaluation of a business idea, it is then time for the businessman to select the best idea. Now, a question arises as to which is the best project.

In this respect, it may be noted that the project which will give the maximum profit with least input should be given a green signal. In other words, the optimum business idea should be selected.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Mr. Khanna always insures his goods while transporting them from his godown to his shop. Name two qualities reflected by Mr. Khanna.

   i) ....

   ii) ....

2. Match the following:

Nature of the business	Ideal location of the business
1) A project meant for manufacturing a perishable product	a) To be located near to the centres from where raw material is easily available
2) Factory	b) To be located near to the port
3) A project based on imported raw material	c) To be located near to the centres of consumption

4.7 LET US SUM UP

Every human being is busy in some activity or the other, categorised as economic activity or non-economic activity. Business is an economic activity, prime motive being to earn profit. The businessman earns profit by satisfying the needs and wants of the customers through marketing. The process of marketing begins with an effort to develop an attractive set of opportunities for the firm. A businessman can choose opportunity from his environment. After the identification of various opportunities, the businessman may evaluate these opportunities in the light of sales potential; financial, technical and marketing aspects. Further the businessman should take steps to translate the identified business opportunity into a viable business idea. The various *sources* from where a businessman can derive business ideas are customers; researchers; competitors; salesmen; business journals; financial institutions; market research agencies etc. Identification of business opportunity and its assessment thereof leads the businessman to generate business ideas, which can translate the opportunity into a profitable venture. The businessman should, thereafter, evaluate the various aspects of business idea. He should, thereafter, choose a project, which will give him the maximum profit with minimum of input resources.

4.8 KEY WORDS

Business environment : It is a total of all external factors, which affect the organisation and operations of business. Consumers, suppliers, competitors, government etc. constitute the business environment.

Business risk : A Possibility of loss due to some unforeseeable, unpredictable or unfavourable events which may occur in future.

Fixed capital : Amount of money invested in purchasing non-recurrent assets, which will give benefits to the business for a relatively longer period of time.

Location : A fairly broad area like a city, industrial zone or a coastal area.

Trade : Buying and selling of goods and services.

4.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Prepare such festival sweets and sell them.
2. He thinks of grinding the whole spices in his own *chakki*. Kailash Nath thus identifies a business opportunity.

Check Your Progress Exercise 2

1. i) Economic Times
   ii) Financial Express
2. They are the ones who are the end users of the product. Consequently, they are in a position to tell the problems faced in using the product. Their unsatisfied needs and wants may lead to development of a new product or improvement / value addition in the existing product.

Check Your Progress Exercise 3

1. i) T ii) F iii) T iv) T v) F

2. i) Add topping of onion and tomato and spices etc. along with cheese.

   ii) Break and crumble the biscuits. Add Bikaneri Bhujjia, onion and other spices. And mix a few drops of lemon.

Check Your Progress Exercise 4

1. i) Cautious
   ii) Good Planner

2. 1) c 2) a 3) b

4.10 SOME USEFUL BOOKS

1. Bhushan, Y.K. (2005) Fundamentals of Business Organisation and Management. Sultan Chand and Sons, New Delhi.

2. Chandra, Prasanna (1996) Projects, Planning, Analysis, Selection, Implementation and Review, Tata McGraw-Hill Publishing Company Limited, New Delhi.

3. Kotler, Philip (2004) Marketing Management – Analysis, Planning and Control, Prentice Hall of India, New Delhi.

4.11 ASSIGNMENTS

1. Why should business risks be assessed while evaluating the business idea?

2. List any two examples of risks, which a businessman may have to bear.

3. “A businessman has to be innovative”. Justify the statement.

4. Name two purposes for which a businessman may need fixed capital.

5. What are the benefits of product imitation?

6. Explain briefly the various sources from which business idea can be generated.

7. “A businessman should not keep his mind locked”. Do you agree? Give reasons.

8. How can business opportunities be assessed?

UNIT 5 MARKET ASSESSMENT

Structure

5.0 OBJECTIVES

After studying this unit, you should be able to:

- get a clear view about the needs for market assessment;
- distinguish between needs and wants of the consumers;
- understand the meaning of market and marketing;
- identify and comprehend the process of market assessment;
- know about market segmentation and market targeting; and
- understand the market size for the business idea.

5.1 INTRODUCTION

Market assessment is referred to as an important step in the setting up of a business and its successful continuation. The key to success in a business lies in getting into the right business at the right time. This is easier said than done. Its accomplishment is difficult because good business opportunity tends to be elusive. Identification of such opportunities requires imagination, sensitivity to environmental change and realistic assessment of what the firm can perform.

Identification of opportunities and their assessment have been discussed at length in the previous unit. After the business opportunity is translated into an effective business idea, then starts the work of market assessment. You may note that before the commencement of any business (either a new business or the expansion of existing business) the need for assessment of market always exists. Need for market assessment will arise in:

- Survival of the business;
- Growth and development of the business;
- Diversification of the business;
- Desire for higher revenue;
- Facing competition
- Building brand recognition.
- Maintaining reputation and prestige of the business;
- Keeping customers;

- Changing tastes and fashions;
- Maintaining good relations with Government Departments and other relevant factors.

5.2 CONCEPT OF MARKETING

In this Unit we will study the various aspects of market assessment.

The concept of marketing cannot be understood in isolation. The meaning of marketing is inter-woven in the concept of human needs and wants, products, exchange process and the market. Let's start our journey of finding the meaning of the term marketing through these concepts.

Concept of needs and wants

Every human being living on this planet earth is a bundle of needs and wants. All of us –keep on working throughout the day in order to fulfil a purpose – the purpose being to satisfy various needs and wants.

What is a Need: A need is a state of felt deprivation of some generic satisfaction arising in the human conditions. People need air, water, food, clothing, shelter etc. These are basic needs, which have to be fulfilled for very survival. Man's needs are few and limited.

What is a Want: Wants are desires for specific satisfiers of the ultimate needs. A person needs food to survive but the same person may want a pizza, burger, cake or biscuits to satisfy his wants. A person may need water to quench his thirst but may want to have a drink of cola, apple juice, rose sherbet, tea or coffee.

As compared to man's needs, which are few and limited, his wants are unlimited. The list of wants is large and keeps on growing.

The wants of human beings are not static. They keep changing depending upon changing social patterns and life-styles, income etc. A person today may be contented with Maruti 800 but say, two years later the same person may want to own a Honda City or a Sonata.

Activity

In the following Table, three types of needs are given. Based on this, think and list four types of wants, which a person would like to fulfil.

Needs	Wants
a) Men's clothing	1. 2. 3. 4.
b) Women's clothing	1. 2. 3. 4.

c) Shelter	1. 2. 3. 4.
d) Relaxation	1. 2. 3. 4.

Hint:

A. Safari, Silken Kurta Pyjama, Designer Suit, Jeans
B. Silk Saree, Leather Coat, Jamawar Shawl, Expensive Evening Gown
C. Flat, Farm House, Big Bungalow, Haveli
D. Dancing, Yoga, Meditation, Gym

Concept of product

A human being is in a position to satisfy his needs and wants through a product.

A product includes any object, service, activity or place through which a need or a want may be satisfied.

For example a product can be an 'object' like apple juice or it can be 'service' like showing of a play at a theatre or it can be an 'activity' like taking part in dancing during harvesting season, festivals etc. or it can be a 'place' like visiting 'tea gardens' at Palampur.

Concept of exchange

As already said, a person is in a position to satisfy his need through a product. How is the product to be made available to him? The product can be made available to any person through the process of exchange. The exchange can be through:

Barter: A person in need of wheat offers rice to another person and exchanges wheat for rice with him.

Money: For example, a hungry person may give money to get a cheese patty i.e exchange money for a cheese patty.

Getting a service: A person gets his clothes washed by another, giving him food in return.

After understanding these terms, we can now proceed to discuss what market and marketing mean.

Concept of market

The word market has its origin in the Latin word "Marcatus". It means merchandise, ware or trade. A market is the set of all actual and potential buyers of a product.

Traditionally, the term market was used to refer to a place where buyers and sellers met for exchange. But now, due to the growth and development of technology, buyers and sellers can conduct business without meeting at a place. Dealings can now be done through telephone, mail, Internet, etc.

Internet has no doubt created a revolution. It has given rise to a virtual market through which a seller can reach any customer anywhere, anytime; and so can the buyer reach the seller.

The term market in a wide sense is the set of all actual and potential buyers of a product. It takes into account the fact that whenever there is a need or a want and the wanted product is available for sale or exchange - a potential for trade: there is a market.

The term market can be looked upon from many directions.

Place of business: The term market, in common language, is used for a place where business is conducted. It is a place where customers go to purchase various goods to satisfy their needs and wants e.g. Lajpat Nagar market in Delhi and find sellers offering those goods for sale or exchange.

Nature of the products: The term 'market' may also suggest the nature of the product, which is traded there. For example, subzi market, cloth market, etc.

Volume of trade: The term 'market' is also at times used to indicate the volume of trade, which takes place between the buyer and seller. The place where goods are traded in bulk is called wholesale market and where goods are sold in small quantities is called retail market.

Concept of marketing

Marketing means working in and for markets. It can be referred to as an exchange transaction that takes place between the seller and the buyer. The needs and wants of the buyer and seller are met through the exchange transaction. Marketing is, therefore, a human activity directed at satisfying needs and wants through exchange process.

According to Philip Kotler, marketing is a "social process by which individuals and groups obtain what they want through creating, offering and freely exchanging products and services of value with others."

5.3 HOW TO ASSESS MARKET FOR ANY BUSINESS IDEA

A number of factors are to be considered for the assessment of the market (Figure 5.1). A businessman must take these factors into consideration while assessing the market. Following diagram depicts the factors affecting the assessment of market.

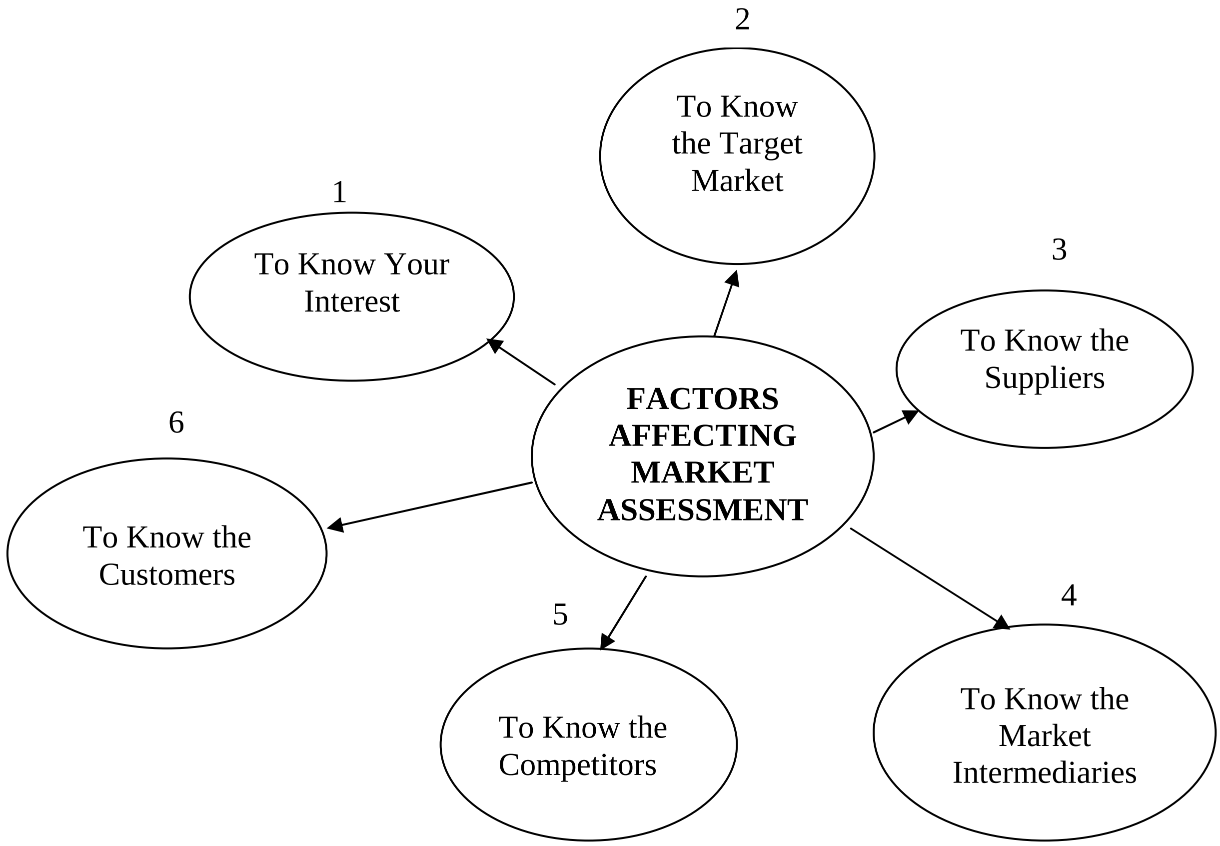


Figure 5.1: Diagrammatic presentation of factors affecting market assessment

Let's now discuss these factors:

1. To Know Your Interest

Before assessing the market, the businessman must first assess himself – he being a part of the market as well.

Have you ever pondered over whether all the people who thought of starting and running a good business were able to do so? Were they all successful in their mission to enter the market and then grow and develop, face the competition and so on.

Well, the answer is that a few businessmen did succeed in their objective whereas there were unlucky ones who did not. They could not muster any grip over the market, made wrong decisions and had unhappy experiences.

What were the consequences of the above-mentioned happenings? Gradually their business showed losses year after year and the saying "started with a boom and ended with a whimper" fully suited them.

Did these people really look into themselves before they started? Did they realize that they were poor planners or did not have an alert and dynamic mind, were visionless etc.

Because of their weaknesses resources (money, human workforce, natural resources etc.) got wasted leading to personal, social and national wastage.

Therefore it is the duty of every person who is thinking of starting a business to ask himself:

- Is he really ready to face the market?
- Is he able enough to survive in the market?
- Can he plan a strategy to save himself from losing in the competition?
- Will he be able to fulfil all the economic, social, national objectives of entering business?

A businessman needs to have certain qualities. Some of the qualities may be inherent in his nature, whereas a few of them can be imbibed. Without these qualities, it will be difficult for a businessman – whether working on a small scale or large scale – to survive, grow and expand his business.

The qualities, which are very essential for any businessman are as follows:

Personal Qualities:

- Equable temper
- Pleasant behaviour
- Considerate nature
- Openness

Physical Qualities

- Good health
- Stamina
- Impressive personality

Mental Qualities

- Clear mind
- Confidence
- Enterprising
- Practical skills
- Rational judgment
- Good memory

Education and Training

- Minimum qualification required for that particular kind of activity
- Training in required skills
- Knowledge of business methods
- Knowledge about maintaining accounts and
- Complying with legal and government regulations

Qualities to Tackle Customers (Customer Oriented Qualities)

- Should act as a friend, philosopher and guide
- Maintain good interpersonal relations
- Have patience

Competition Oriented Qualities

- Dynamic
- Flexible
- Alert to opportunity
- Quick reflexes

- Creative
- Innovative
- Foresighted

Moral Qualities

- Honest
- Truthful

Managerial Qualities

- Good planner
- Rational decision maker
- Good motivator
- Good leader
- Good communicator
- Good listener
- Good organizer
- Careful – not rash
- Willing to accept challenges
- Risk taker

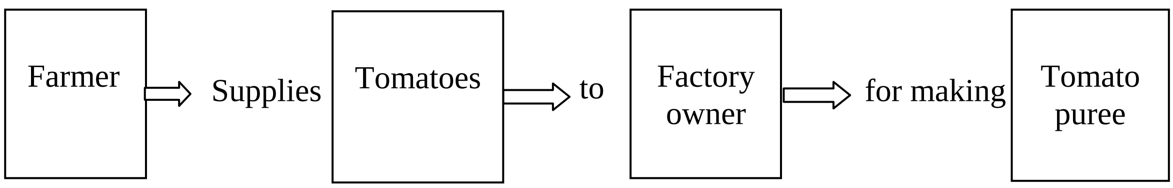
2. To Know the Type of Target Market

The businessman needs to decide on the market, which he wishes to cater to or enter. He may find two types of markets:

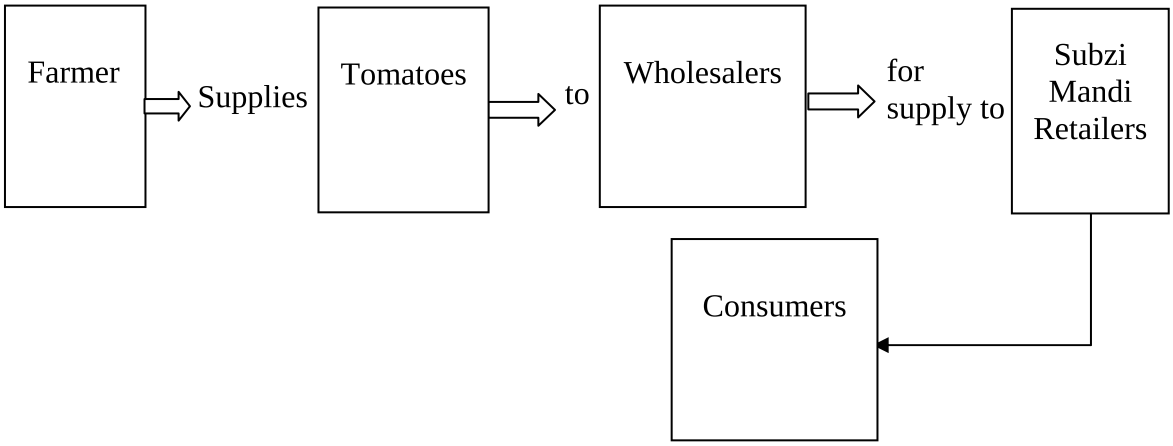
a) Producer Market; and
b) Consumer Market.

These are explained in the subsequent paragraphs.

a) *Producer market:* The goods supplied to industrial market are usually in the form of raw material and for further production not for final consumption. The raw material is processed and converted into finished product. It is then sold to the consumers. For example, tomatoes are processed in the factory, and converted into tomato puree. This process is depicted through the following diagram in which the farmer (i.e. businessman) supplies tomatoes (i.e. raw material) to the factory owner (i.e. industrial market) for converting into tomato puree (i.e. output):



b) *Consumer market:* The 'consumer market' comprises various consumers. The goods purchased from this market are for direct consumption. The buyer of the product is the final user. He purchases the finished product to satisfy his needs and wants. This process is depicted through the following diagram in which the farmer (i.e. businessman) supplies tomatoes (i.e. finished product) to wholesalers (i.e. middlemen) for further supply to subzi mandi (i.e. consumer market) and for final consumption by the consumers:



3. To Know the Suppliers

The businessman in order to produce something must acquire a number of inputs needed in the production process. These are made available through a number of suppliers.

There are many kinds of suppliers for various inputs.

Input No. 1 – Money: There are various sources for arranging finance. The businessman can pool his own savings. Money can also be obtained from other sources like friends and relatives, commercial banks, co-operative societies, Regional Rural Banks etc.

Input No. 2 – Manpower (Human resources): The number and type of workers needed by a businessman depends upon the nature and scale of his business operation. A large-scale business may need clerical staff, managers, accountants, workers etc. whereas a small businessman may need only a couple of helpers.

Input No. 3 – Material: The businessman should know the type of material required to make the product. The businessman needs to deal with the suppliers of raw material. The raw material like oil seeds, cotton, fruits, vegetables and other agro-based products can be obtained from the cultivators or Agricultural Produce Market.

Input No. 4: Machines: The tools, equipment, machines etc. can be purchased directly from the manufacturers of these items or their agents. Some of the machines can be imported also depending upon the cost-effectiveness.

Input No. 5 – Information: The businessman needs to gather information as to the latest machines available or latest methods of production etc.

For a bird's eye view let's look at the following diagram, which shows the various types of suppliers. These are also known as five M's of marketing.

M **E** **N**	**M** **A** **T** **E** **R** **I** **A** **L**	**M** **A** **C** **H** **I** **N** **E**	**M** **O** **N** **E** **Y**	**M** **E** **T** **H** **O** **D** **S** **(Information)**

(Five M's of Marketing)

The businessman should also keep in mind the strength of suppliers. At times, the suppliers of above inputs are in a dominant position and dictate their own terms and conditions to the businessman.

Activity

Roop and Swaroop are two close friends living in a small town of Uttranchal. They are planning to deal in following types of packed spices:

- Red Chili Powder
- Turmeric Powder
- Dhania Powder
- Chana Masala Powder
- Chaat Masala Powder

How will they assess their market in terms of their suppliers? The market assessment may be filled in the following Table:

Sl. No.	**Inputs**	**Decisions regarding the availability of inputs**
A.	Men	1. 2. 3. 4.
B.	Material	1. 2. 3. 4.

C.	Machine	1. 2. 3. 4.
D.	Money	1. 2. 3. 4.
E.	Method	1. 2. 3. 4.

Hint:

A. Production Manager, Marketing Manager, Workers etc.
B. Red Mirchi, Turmeric, Dhania Seeds, Spices
C. Grinding Machine, Sieves, Packing Machines, Other Tools and Equipment
D. Own Savings, Funds from Friends and Relatives, Borrowings from Banks, RRBs
E. Offices of SSI, Economic Survey of India, FICCI, CII, STC

4. To Know the Marketing Intermediaries

Marketing Intermediaries act as the middlemen or 'go-between' for the businessmen and the market i.e. the consumers. They help in the distribution of the output of the businessmen to the market. To make this clearer, let's study the case of Neelam.

25-year old Neelam lived in Himachal Pradesh. She was a born painter. As a hobby, she made, lovely landscapes, portraits, other paintings using vegetable colours as the medium. To improve her standard of living, she thought of selling those paintings and soon thereafter, she along with her husband, started selling them to the rich families of nearby areas. Sale of the paintings was a morale booster for her. At this stage, an idea struck her mind. If she could make more paintings and sell them to a wider range of people? With full determination she started doing the work and in the next two months she made twenty-five beautiful paintings using vegetable colours. It was the time for the tourists to flock to these cool refreshing hill stations. Within a week's time she and her husband were able to sell off all the paintings. This made them to earn an unimaginable figure of Rs. 15,000.

One of the tourists hailing from Delhi was greatly impressed by her paintings. Luckily, he was known to Neelam's neighbours. He suggested to Neelam to sell the paintings in hi-fi shops of Delhi. He said that she would fetch a handsome price for these lovely creations of hers. Neelam and her husband liked the idea but there was nobody to guide them and help them in selling paintings in Delhi. This made them sad. But the tourist solved their problem. He said that he was a very influential person and knew a lot about the market and people of Delhi. He could take her paintings to Delhi and sell them to the hi-fi shopkeepers on commission basis. Accordingly, the deal was made.

Now, who is this Mr. Tourist? What is his role in the entire process of exchange? Well, he is acting as an intermediary. He is the middleman between Neelam and the shopkeepers of Delhi, whom Neelam does not know.

There are three kinds of intermediaries as explained below:

i) *Merchant middlemen:* They are business units (like wholesalers and retailers). They buy, obtain title to the merchandise and sell them further.

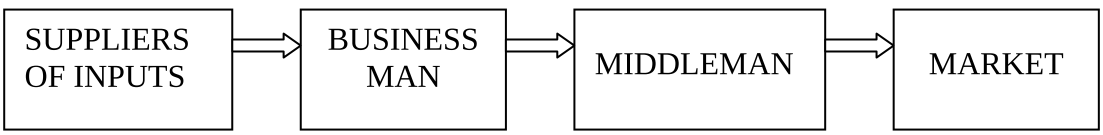
ii) *Agent middlemen:* They are the business units (like brokers and sales representatives). They negotiate purchase or sale of merchandise but do not take possession of title thereto.

iii) *Facilitators:* They are business units that assist in the performance of distribution function. They neither take possession of title to goods nor negotiate purchase or sales of merchandise e.g. transporters, warehouses, bankers etc.

The businessman seeking distribution of his goods must either use established marketing intermediaries or set up his own system of distribution. The existing marketing intermediaries have the experience. However, if the businessman finds these intermediaries to be inadequate for his needs, he can establish his own network. Direct marketing can be the way to reach the final consumers through:

- Sales force
- Direct mail
- Telephone
- Internet

The role of intermediaries can be represented with the help of the following diagram:



5. To Know the Competitors

I think you'll agree with me if I say that a particular businessman is not standing alone as a seller in the market. There are others too in the trade.

For example Babu sells oranges on his 'Thela'. Now, is he the only person selling oranges? No, there are many others on the same street, in the colony or in the entire area.

The businessman must realize that other businessmen are also putting in equal amount of hard work, efforts, and dedication. There are a number of things, which the businessman should know, to compete with his business rivals or competitors. He should:

- Know about the number of firms in the same industry;
- Know about the market share of the top few firms;
- Know about the degree of homogeneity and differentiation in respect of his product;
- Know about the entry barriers operating in the market;
- Compare his product with the substitutes in terms of quality, price and appeal;
- Know about the market policies and practices.

The strength and weakness of the competitors also need to be found out and analysed. The businessman will compete most closely with those competitors who occupy a similar position or niche in the market. The businessman should therefore identify and monitor most closely those competitors who are seen to be close to him in the minds of the consumers.

6. To Know the Customers

Customers consist of all the individuals and households who buy or acquire goods and services for personal consumption.

There may be different types of customers in the market like old and young, poor and rich, illiterates and educated etc. The businessman should be able to distinguish different groups and develop products tailored to their particular needs. For example, a new type of custard powder or ice cream may be developed to attract the young generation.

With a view to knowing the customers, the businessman should ponder over the following aspects:

- *What do people buy?*

  The customers may buy the following kinds of goods:

  i) Durable Goods: These are tangible goods, which can be used again and again, comparatively for much longer period of time. These may include furniture items, utensils etc.

  ii) Non-durable Goods: These are the goods, which are usually consumed in one go or are meant for few uses – say, fruits, vegetables, ketchup etc.

  iii) Convenience Goods: These goods are purchased very often for immediate use by the customers. The consumers will not compare the product with any other product before purchasing e.g. bread, buns, sugar, salt, food-grains etc.

  iv) Shopping Goods: These goods are purchased after due comparison with other products in terms of quality, price etc. e.g. tea, sherbets, shoes, cosmetics, furniture, etc.

  v) Specialty Goods: These are the goods, which have some unique features and brand identification. The buyer will make a special effort in purchasing these items e.g. Chocolate, sauce, Badam-Pista mixture, imported chocolates, ready-to-eat curries, olive oil, Badam rogan, television, washing machine, car, imported fruits, etc.

Activity

Visit the nearby market in your area and gather the following information for completing the Table given below:

Product	Available brand	Price	Size/weight
Tea			
Strawberries			
Imported Fruits			

- *When do consumers buy*

  The businessman should analyse the timing of purchase. A consumer may buy a product frequently or the consumption rate may be low e.g. a family with young children may buy more of chocolates, potato chips etc. compared to roasted dalia.

  The consumer may also buy at the time of festival e.g. sweets at the time of Deepawali, new clothes at the time of Rakshabandhan, rock salt and kutu atta during the 'Navratri days' when people keep 'fast', sewyian during Id, etc.

- *What do consumers want*

  The consumers purchase goods to satisfy a variety of their needs. These needs may be physiological, spiritual, social, psychological, etc. Each product offers the buyers certain amount of utility. The customers weigh whether utility derived from the product matches the price paid by them.

- *How do consumers buy*

  The businessman should study the buyers' decision-making processes that lead to a particular 'buying decision'. The businessman must try to understand the various cultural, social, and personal factors that operate to shape the life-styles of the customers. For example, in the case of apple jam, a person living in urban area may like to purchase it but the same may not appeal to a person who is living in rural area. A villager may like more to use mango chutney. Other factors, which may influence 'buying decision', include features of the product, its price, its quality, after-sales service provided by the seller, etc.

  Buying process starts when the consumer feels the need for a product. Thereafter, he generally continues with the following buying process:

  i) In order to fulfil his needs the consumer seeks information from his environment. He tries to gather more awareness about the product that would satisfy his need;

ii) The consumer after securing information develops an attitude – positive or negative – towards the product;

iii) If a favourite attitude towards the product is developed, the consumer tries the product on a small scale;

iv) Finally, if the trial is successful, he may buy the product – he may even become loyal to the product or brand.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Read the following and answer the questions that follow:

   "Raj Kishore has a mango garden in his village. He sells the mangoes grown in his garden to a firm of Sonepat namely, "Home-made Pickles" for making mango pickles.."

   i) Will the mangoes sold to "Home-made Pickles" be used by the owner of the firm and his family for personal consumption?

   …..……………………………………………………………………….

   …..……………………………………………………………………….

   …..……………………………………………………………………….

   ii) Why is the firm buying the mangoes?

   …..……………………………………………………………………….

   …..……………………………………………………………………….

   …..……………………………………………………………………….

   iii) If Raj Kishore plans to sell mangoes in the fruit market, who do you think will be the final users?

   …..……………………………………………………………………….

   …..……………………………………………………………………….

   …..……………………………………………………………………….

2. Krishna Kumar wants to make and sell vegetable sauce. List the kind of workers, he will employ:

   i) ……………………………………………………………………….

   ii) ……………………………………………………………………….

   iii) ……………………………………………………………………….

   iv) ……………………………………………………………………….

   v) ……………………………………………………………………….

3. Why has the businessman to identify and monitor his competitors?

…………………………………………………………………………………

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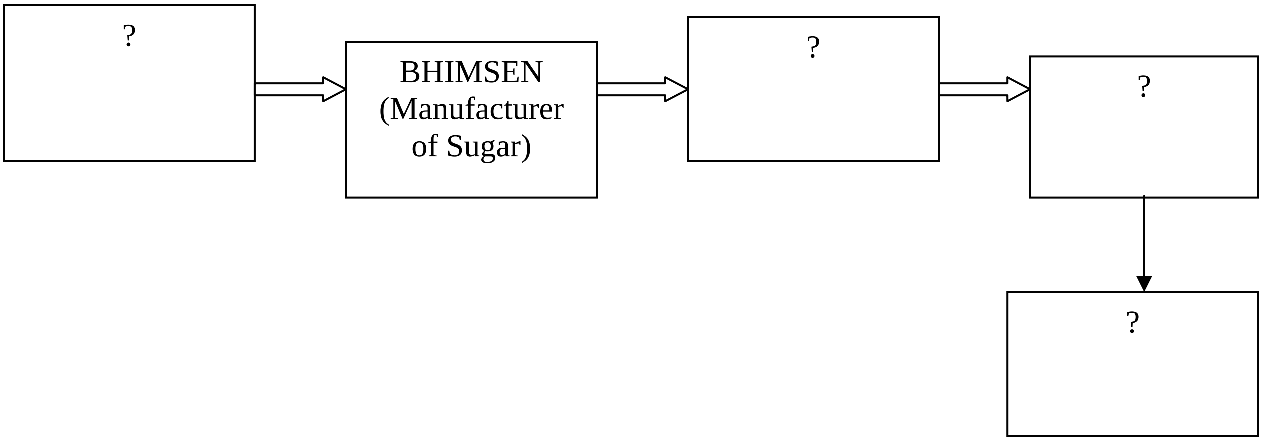
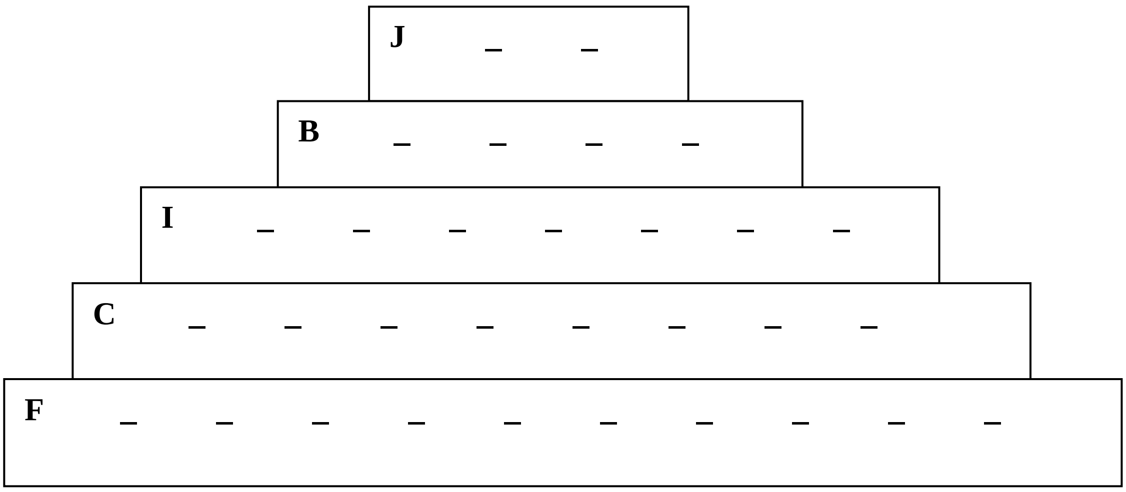
4. Bhimsen is a businessman owning a sugar mill in District Meerut. Identify his suppliers of raw material, middlemen and the market and complete the process given below:



5. Fill the following pyramid on the basis of under-mentioned information:

- A business unit that assists in the performance of distribution. (11 letters)
- A source from where money can be arranged. (5 letters)
- A source of direct marketing. (8 letters)
- The individuals who buy goods for personal consumption. (9 letters)
- A sweet consumer product, which is manufactured using fruit as a raw material (demographic segmentation – small children). (3 letters)



5.4 WHAT CONSTITUTES THE MARKET FOR YOUR BUSINESS IDEA

Market consists of consumers. A market for any businessman comprises those persons who he thinks will buy his product. A businessman desiring to cater to the consumer market should understand the fact that consumers vary widely in their characteristics. They may differ in age, geographical location, income, education level, taste, product requirements, buying attitudes (a family may buy bananas only on Mondays), etc. Any of the above aspects can make a difference in customers' fancy or in the capacity of the firm to effectively serve that customer.

From the above it can be interpreted that the consumer market is not fully homogeneous but is heterogeneous in nature. The heterogeneous market can be broken down into a number of homogeneous units. This division of market is called market segmentation. The businessman through market segmentation, aims to satisfy the needs of the customers in a much better way. He tries to focus sharply on each of the different customer groups or any one of the customer groups within a market. Market segmentation leads to market targeting. In this Unit we will study about market segmentation and market targeting.

MARKET SEGMENTATION

A business unit normally is not able to serve all the customers. It may be due to the fact that there are too many customers in the market. Again, all of the customers are widely scattered. Moreover, some competitors will be in a better position to serve the customers in the market.

If the resources are limited, then the business unit should try to identify those market segments that it can best serve in terms of segment preferences, patterns of competition and the strength of the business.

There are many ways in which a market can be segmented. These are discussed below:

1. *Geographical segmentation (Geographical markets)*

   In geographical segmentation, the businessman divides the market into different locations – neighbourhood towns, cities, districts, states, country and international markets. The businessman will target a particular geographical market keeping in mind the market potential and the costs incurred to reach the market e.g. Amul initially marketed its products only in Gujarat.

2. *Demographic segmentation*

   Under demographic segmentation, the businessman divides his customers on the basis of age, gender, family size, city size, religion, language, occupation, educational level etc. For example, in the case of chocolates and beverages, the target customers are young children and adolescents.

3. *Buying behaviour segmentation*

Under buying behaviour segmentation, customers are divided on the basis of purchase decisions made by them. The idea behind this is that different customer groups expect different benefits from the same product and as such their motivation in owning it and their behaviour in buying it will be different.

4. *Benefit segmentation*

Under benefit segmentation, the consumers are classified according to the benefits they derive from the product. For example, benefits derived from 'Amla Murabba'.

5. *Volume segmentation*

The quantity of purchase is another basis used for dividing the customers. There may be bulk buyers, small-scale buyers, regular buyers and one-time buyers.

6. *Economic segmentation*

Under economic segmentation, customers are divided on the basis of their income level. For example, Mother Dairy ice creams are available in different price ranges so that anybody according to his income level may purchase the same. In bakery shops we may find a variety of cakes like vanilla cake, chocolate cake, truffle cake, etc. A customer may buy a particular cake, which suits his income level.

7. *Psychographic segmentation*

This kind of market segmentation is done on the basis of customers' attitude, opinion, interests etc. or a combination thereof.

MARKET TARGETING

Market segmentation leads to market targeting. Market targeting is the process of fixing target market.

You may note that process of market segmentation opens up not one but several market segments. These segments will have varying potential, profitability and the degree of risks. The firm must evaluate the worth of each segment in terms of whether it is sizeable, accessible, attractive and profitable. The firm may not be interested in all the segments. Some may give high profitability but may need heavy initial investments. Some may have potential but the firm may face tough entry barriers. Thus, the firm needs to select one or more segments as the target market. The segment selected as target market must be most appropriate to the firm. This is what constitutes the market for a particular business idea.

With the help of market targeting, the businessman is in a position to identify the markets and the group of target customers for whom he plans to produce products. Market targeting is the act of evaluating and comparing different identified groups. After evaluation and comparison the businessman may select one or more of the identified groups as the prospective customers with the highest potential. Thereafter a suitable marketing mix may be devised that will give the best return on sales.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State True or False:

   i) The businessman must look at each market segment as a distinct marketing opportunity.

   ii) Market segmentation must be relevant and profitable to the businessman.

   iii) Market targeting leads to market segmentation.

   iv) Consumer market is fully homogeneous.

   v) Target market can be fixed at random.

2. Match the following:

i) Location	A) Economic segmentation
ii) Age	B) Geographical segmentation
iii) Quantity	C) Buying behaviour segmentation
iv) Income level	D) Demographic segmentation
v) Purchase decision	E) Volume segmentation

3. 'Swadeshi Beverages (Pvt.) Ltd.' is planning to launch a health drink for old people. On which base would they segment their market?

   ……………………………………………………………………………………

   ……………………………………………………………………………………

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5.5 MARKET SIZE FOR YOUR BUSINESS IDEA

Meaning of market size

Market size means the actual volume that is currently being purchased by the customers. It can be measured in terms of rupees or units. It is always smaller than the total market potential.

Meaning of total market potential

Total Market Potential is the maximum amount of sales that might be available to all the firms in an industry during a given period under a given level of marketing effort and given environmental conditions. It is also measured in rupees or units.

Assessment of market size

Assessment of market size depends upon the following two factors:

i) Market demand: This means the total volume that would be bought by a customer in a defined time period. A product should have a demand in the market. A demand is said to be there when a person has some interest in that product and he also has the purchasing power i.e. necessary resources for purchasing the product.

To assess the market size, the businessman should undertake *demand forecasting*. Some of the methods, which a businessman may use for demand forecasting, are:

- *Survey method:* Under this method the businessman tries to gather information in respect of demand for his product. In this connection he obtains information from sales representatives, prospective customers, suppliers, experts etc. Based on the information collected, he calculates the demand for his product.

- *Leading indicator method:* Some leading indicators may show the trend of future. Now-a-days frozen vegetables (like peas) have a huge demand. This being a leading indicator, the supplier of packaging material, in which the frozen vegetables are packed, may anticipate that there will be huge demand for packing material also.

- *Statistical methods:* Certain statistical methods like multiple regression analysis and time series may be used to forecast the demand.

ii) Price: The size of the market will vary with price. A high price of a product may create a small market whereas a low price of the product may fetch a larger market. This is due to the fact that more people can afford to purchase the product.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Fill in the blanks:

   i) ----------- is the maximum amount of sales that might be available to a businessman.

   ii) ----------- is the actual volume that is currently being purchased.

   iii) A product should have a --------------- in the market.

   iv) High price shall have ------------- market.

   v) ---------------- is the total volume that would be bought by the consumers.

2. Name any one unit of measurement, which may be used to measure the market size.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

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5.6 LET US SUM UP

For setting up a business and its successful continuation, market assessment has an important role to play. Before understanding the term market assessment, it is a must to understand concept of needs and wants, concept of product, concept of exchange, concept of market and concept of marketing. A number of factors affect market assessment. These factors include knowledge of self (i.e. self-assessment); knowledge of the type of target market; knowledge about the suppliers; knowledge about the intermediaries; knowledge about the competitors, and knowledge about the consumers. Market consists of consumers. Consumer market is not fully homogeneous but is heterogeneous in nature. The heterogeneous character of the market may be broken down into a number of homogeneous units and this kind of division of market is called market segmentation. Market can be segmented on the basis of geographical segmentation, demographic segmentation, buying behaviour segmentation, benefit segmentation, volume segmentation, economic segmentation and psychographic segmentation. Market segmentation leads to market targeting. With the help of market targeting, the businessman can identify the market and the group of target customers. Market size also plays an important role. Assessment of market size depends upon market demand and the price of the product.

5.7 KEY WORDS

Market segmentation	:	Division of market on certain bases.
Product	:	Any object, service, activity or place which helps in satisfying a need or a want.
Wholesaler	:	A middleman who purchases goods from the manufacturers in bulk and sells to the retailers.
Retailer	:	A middleman who purchases goods from the wholesalers and sells to the ultimate consumers.

5.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include following points:

1. i) No ii) For making pickles iii) Consumers

2. i) Persons in the factory ii) Clerical staff iii) Accountant
   iv) Receptionist iv) Marketing Manager

3. To gain and maintain loyalty of the consumers.

4. Farmer; Wholesalers; Retailers; Consumers

5. Words to be filled in the pyramid are:

   - Facilitator
   - Banks
   - Internet
   - Consumers
   - Jam

Check Your Progress Exercise 2

1. i) True ii) True iii) False iv) False v) False

2. i) B ii) D iii) E iv) A v) C

3. Demographic

Check Your Progress Exercise 3

1. i) Market potential
   ii) Market size
   iii) Demand
   iv) Small
   v) Market demand

2. Rupees

5.9 SOME USEFUL BOOKS

1. Gupta, C.B. and Rajan Nair, N. (2000) Marketing Management, Sultan Chand and Sons, New Delhi.

2. Kotler, Philip (2004) Marketing Management – Analysis, Planning and Control, Prentice Hall of India, New Delhi.

3. Ramaswamy, V.S. and Namakumari, S. (1998) Marketing Management (Planning, Implementation and Control – The Indian Context), Macmillan India Limited, Delhi.

4. Varshney, R.L. and Gupta, S.L. (2000) Marketing Management (An Indian Perspective); Sultan Chand and Sons, New Delhi.

5.10 ASSIGNMENTS

1. Elaborate the term ‘market’ and ‘marketing’.

2. Mention in brief the procedure, which a consumer may follow in buying the product.

3. What is the difference between wholesalers and agents?

4. What is Market Segmentation? In which ways can a market be segmented?

5. Classify the following products into convenience goods, shopping goods and specialty goods:

   i) salt
   ii) sugar
   iii) shoes
   iv) air conditioners
   v) clothes
   vi) bread
   vii) cars

6. Explain the following:

   i) Geographical Segmentation;
   ii) Demographic Segmentation

7. Distinguish between convenience goods and specialty goods on the basis of price and sale effort.

8. Name the two factors on which the size of market depends.

9. Enumerate the various qualities, which a businessman needs to assess himself.

10. Explain briefly the methods of demand forecasting.

UNIT 6 WHAT DOES MARKETING INVOLVE?

Structure

6.0 OBJECTIVES

After studying this unit, you should be able to:

- refresh the understanding of marketing;
- identify the various marketing functions;
- understand the concept of marketing mix;
- comprehend and analyse the 4 P's of marketing mix; and
- apply the elements of marketing mix to the practical world.

6.1 INTRODUCTION

Marketing, as you are all aware of, starts with the consumer and ends too, with the consumer. The businessman takes the consumer to be the king and therefore, the consumer becomes the focal point of all of his marketing decisions. The businessman has become sensitive to the attitudes of the consumer. He therefore, tries to materialize his goals through consumer satisfaction.

Marketing is the central function of any business. The entire business is organized around the marketing function. The businessman emphasizes identification of market opportunity and seeks to convert customer "needs" into "products". The entire business is a customer satisfying process.

The businessman has to get involved in a number of activities to satisfy his customers and thereby earn profit. Marketing consists of all those activities, which involve working through markets. It covers all those activities and processes by which the products are matched with the market. Marketing functions refer to a series of specialised activities involved in the marketing of goods and services.

Let's try to understand these marketing functions in the subsequent paragraphs.

6.2 MARKETING FUNCTIONS

Production of goods by the business gains importance only when they are sold. Marketing enables a businessman to sell his goods to the consumers.

The functions of marketing make goods and services of use to the society by creating form, place, time and possession utilities. Goods are to be processed into different forms to suit the needs of the consumers, creating thereby the form utility. Goods are required to be transported from the place of production to the place of consumption, thereby creating place utility. Surplus goods are also required to be stored in warehouses for deferred consumption, thereby creating time utility. Sale and transfer of goods create possession utility.

The functions of marketing may be broadly divided into three categories:

I) Functions of Exchange;
II) Functions of Physical Supply; and
III) Facilitating Functions.

The diagrammatic presentation of marketing functions (Fig 6.1) is as follows:

MARKETING FUNCTIONS

Functions of Exchange

- Buying
- Assembling
- Selling

Functions of Physical Supply

- Transportation
- Storage (i.e. warehousing)
- Inventory control;
- Order processing

Facilitating Functions

- Marketing Research
- Product Programming and Development
- Standardisation and Producing
- Packaging
- Branding
- Promotion
- Pricing
- Financing
- Risk taking

Figure 6.1: Diagrammatic presentation of marketing functions

Let us now discuss these functions in detail.

I. Functions of exchange

The functions of exchange include activities performed in the transfer of ownership from sellers to buyers. They include:

1) Buying
2) Assembling
3) Selling

1) *Buying function:* A marketer is engaged in the process of transformation. He takes inputs from the environment, converts them into a finished product and then supplies it back to the environment. Buying involves transfer of ownership of the product from seller to buyer.

   A manufacturer buys raw material from the suppliers for using the same in producing goods whereas a trader procures finished goods from the various manufacturers. A trader can be a wholesaler or a retailer. A wholesaler buys the goods for resale to retailers whereas a retailer buys the goods for resale to the ultimate consumers. Efficient buying is very important for success in marketing.

   Goods can be sold at a profit only when they are of right quality and quantity. The following points, known as five R's of best buy, should be kept in mind before any purchase:

   - Right source
   - Right quantity
   - Right quality
   - Right price
   - Right time

2) *Assembly function:* The work of assembly begins only after the goods have been purchased. It implies gathering of products purchased from different producers/manufacturers at some central place. Some times firms assemble goods in big lots, grade them and give their own brand name after packing the goods.

   For example, Niharika Agro Products purchases rice from various farmers, grades them according to the quality, packages in small lots, gives a brand name (Raja Chawal) and sell it to the wholesalers.

3) *Selling function:* Selling is a very important function of marketing. It is vital to the success of any firm because the revenue is earned by the businessman through selling. The businessman on the one hand, earns profits while on the other hand, he makes available the goods and services to the consumers. Selling can be defined as "effecting transfer of ownership in goods by the seller to the buyer in exchange for money".

Selling involves many activities like locating buyers, finding their preferences, persuading them to buy, negotiating the terms of sale, receiving payment and making delivery, and providing appropriate after sale services.

An enterprise may sell goods directly or through agents, wholesalers and retailers.

II. Functions of physical supply

The functions of physical supply refer to the activities involved in the physical movement of the goods. These functions are:

i) Transportation

ii) Storage (i.e. warehousing)

iii) Inventory management

iv) Order processing

v) Delivery

The details of these functions are given as under:

i) Transportation: Transportation is physical movement of material and goods from one place to another. The function of transportation is quite important because goods are not consumed at the place of their production. Customers are located at far away places. Therefore, goods have to be transported. Transport serves as a link between the producer and the consumer. Proper arrangement for the transportation of the product to market is important to the process of marketing. Transport helps to widen the market; to increase the scale of production and to stabilize the prices. The essence of transportation is that the right product reaches the right destination at the right time. Transportation includes decisions like:

- Choice of mode of transport
- Route planning
- Freight consolidation
- Vehicle scheduling

It may be noted that choice of mode of transport depends upon relative costs of different modes, their speed, reliability, frequency etc. Road transport is suitable for short distances and for rough terrains like mountains. Rail transport is ideal for bulky goods and also if the goods are to be sent over long distances. When goods are costly or of perishable nature and where speed counts, air transport should be preferred. Water transport is the cheapest but it slower.

The various means of transport can be depicted in the following diagram (Fig 6.2):

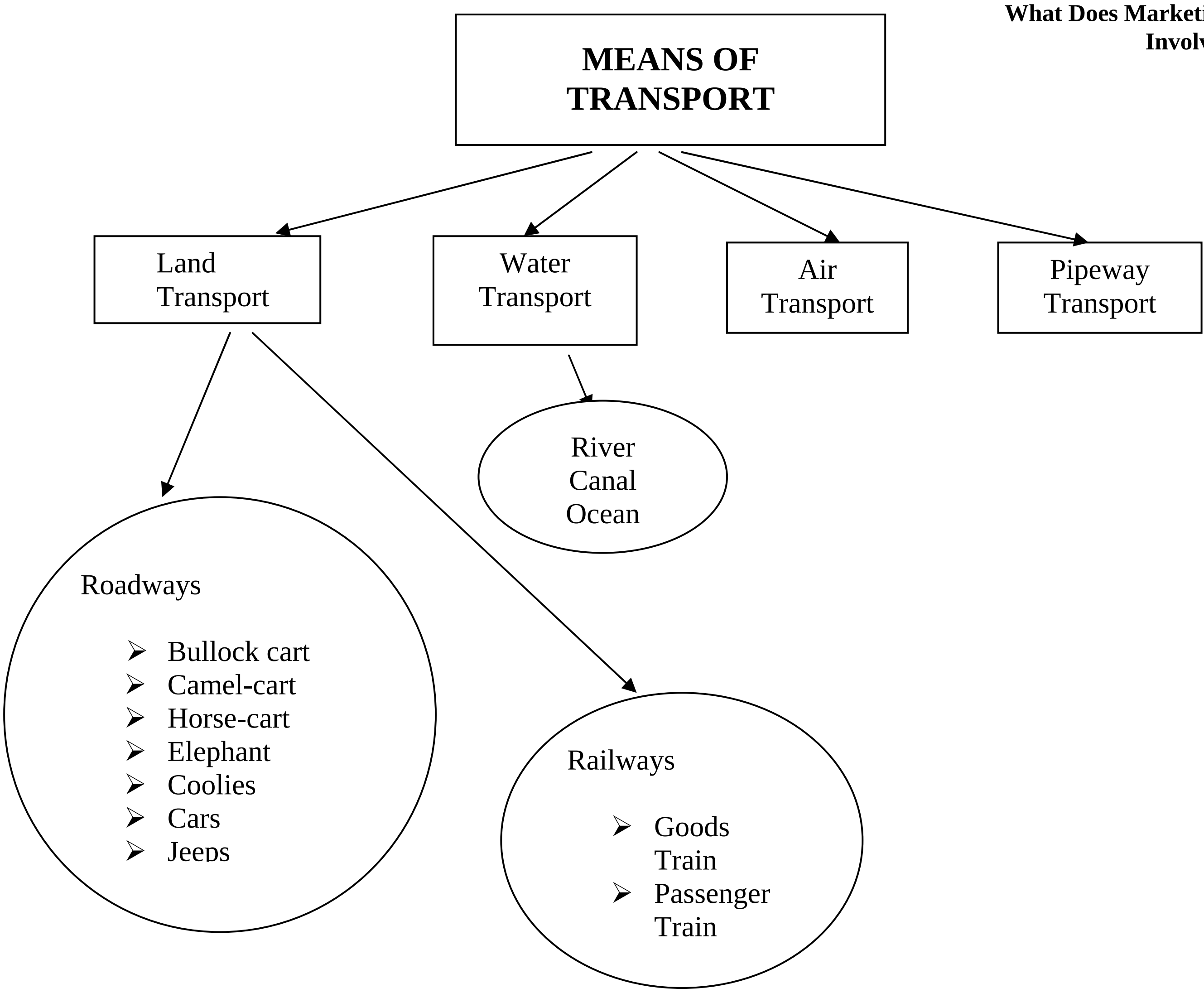


Figure 6.2: Diagrammatic presentation of means of transport

Activity

Tick the appropriate option:

Particulars	Road	Railways	Water	Air
1. Amarnath wants to transport 100 quintals of rice from Bihar to Rishikesh in Uttranchal.				
2. Vinay wants to transport 10 quintals of wheat from Ghaziabad to Bulandsahar.				
3. Ram Singh wants to transport 500 tons of sugar to London				
4. Suraj Nath plans to send 500 kilos of onions from Azadpur Mandi to Okhla Mandi (both places are in Delhi.				
5. Sham Lal wants to send 100 kgs. of rose flowers from Delhi to Chennai.				

(**Hint:** 1. Railways; 2. Road; 3. Water; 4. Road; 5. Air)

ii) *Warehousing:* Another function of marketing process is warehousing. It involves the making of proper arrangements for retaining the goods in a perfect state till the time consumers need them for consumption. Warehousing function is important because there is usually a time lag between production and consumption. With the help of warehouses where goods are stored, uninterrupted supply is maintained so that there is no inconvenience to the user and there is stability in prices. Modern warehouses provide facilities for packing, blending, grading, labelling etc. of stored goods. A manufacturer can secure wider distribution of goods by holding stock at different places. Further the goods get protected from the following risks:

- Fire
- Theft
- Leakage
- Pests, rodents and insects
- Weather changes
- Moisture

The owners may maintain their own warehouses or take the services of warehousing companies. Perishable products like fruits, vegetables etc, are stored in cold storages.

Benefits of warehousing

There are a number of benefits in warehousing. These are:

- Goods can be manufactured or processed in bulk and stored.
- Goods can be stored safety in warehouses.
- It helps in making available the product to the buyers as and when needed.
- It helps in maintaining price stability by adjusting supply with the demand.
- It helps in purchasing goods from far off places as well.
- Commercial banks make available loan on the security of warehouse receipts.
- More imports are possible.
- It facilitates exports.

iv) *Inventory management:* The firm needs to maintain a particular level of stock to ensure product availability as and when customers demand. Holding of inventory involves cost of storage, cost of capital tied up in inventory, cost of adverse price movements, cost of spoilage etc. Inventory control implies control over the size of the inventory. The business firm should weigh the benefits of maintaining inventory against the cost and optimum level should be decided.

iv) *Order processing:* The following steps may be taken to process the order:

- Receipt of order.
- Acknowledgement/Acceptance sent to the customer on receipt of order.
- Customer credit check.
- Inventory scheduling i.e. collection, packing etc.
- Dispatch of goods.

III. Facilitating functions

Facilitating functions refer to the activities involved in helping the process of exchange (Figure 6.3). Following are some of the important functions, which facilitate buying and selling of goods. Every trader is required to take these steps judiciously and carefully.

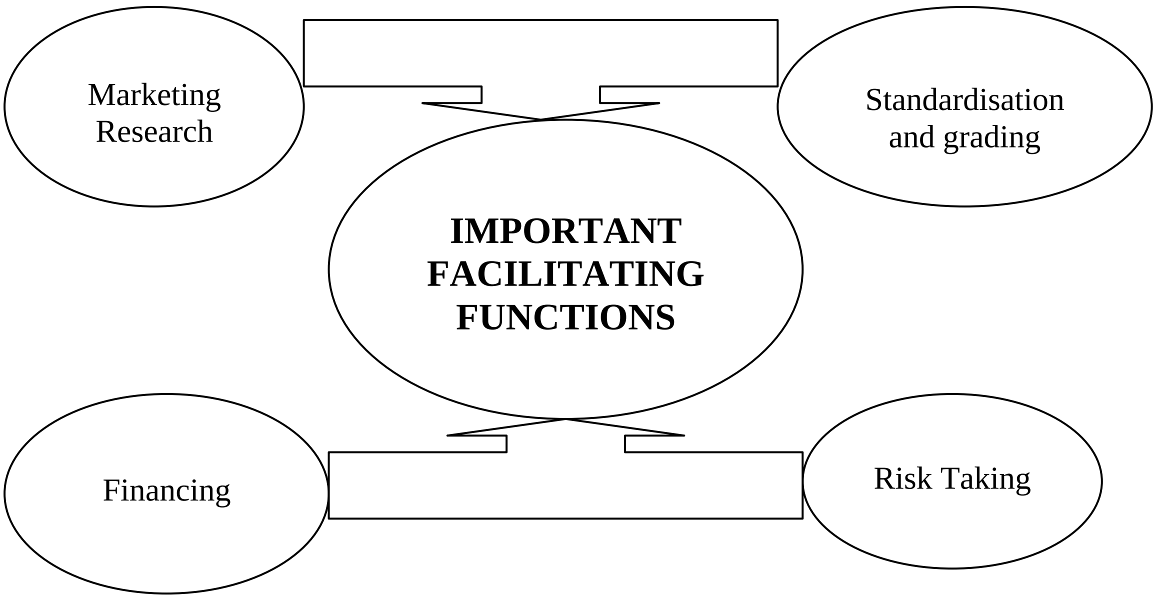


Figure 6.3: Diagrammatic presentation of important facilitating functions

1) Marketing research

American Marketing Association has defined Marketing Research as "gathering, recording and analysing of all facts about any problem relating to the transfer and sale of goods and services from the producer to consumer."

The term 'marketing research' means application of research process in solving marketing problems. Marketing Research equips the marketer in taking all-important decisions correctly. It provides the right information at the right time in the right place and to the right person, which is vital in decision-making.

Uses of marketing research

A businessman can conduct marketing research for the following purposes:

a) *To recognise the needs of the customers:* Marketing Research can be used to identify the various needs and wants of the customers. It involves the study of the market and the customers.

b) *To understand the buying motives:* Marketing Research can be used to understand buying motives of the customers. A customer may buy a product for more than one reason, protection, style, status etc.

c) *To decide the brand name:* A product should have a suitable name. An attractive name always fetches plenty of customers and helps in bringing reputation to the firm. The manufacturer should conduct proper marketing research to decide the brand name of the product.

d) *To decide the size of the package:* The size of the package should be the one, which is convenient in lifting, carrying and storing. A proper size of the package enables proper handling of the product. Ideal size can be ascertained through marketing research.

e) *To decide the method of advertisement:* Advertisement has a great impact on the minds of the customers especially children and adolescents. A good advertising campaign certainly leads to high profits. Marketing Research helps the businessman in deciding the suitable method of advertising.

Classification of marketing research problems

The various marketing research problems can be classified based on the subject matter of research as shown below:

a) *Research on Product:* It includes:

- Reviewing product line, product quality, product features etc.
- Study of the actual uses of a given product;
- Study of the new uses of an existing product;
- Study of packaging, packing material etc.
- Testing of new products.

b) *Research on Markets:* It includes:

- Study of the market size;
- Study of the market segments;
- Short range and long range sales forecasting;
- Study of the overall business trend;
- Analysis of market share.

c) *Research on consumers:* It includes:

- Study of consumer profile;
- Study of the consumer tastes;
- Study of the consumer brand preferences;
- Study of consumer dissatisfactions;
- Study of the consumer reactions.

d) *Research on Advertising and Promotion:* It includes:

- Media research;
- Assessing the impact of advertisement;
- Assessing the effectiveness of sales promotion measures;
- Cost benefit analysis.

e) *Research on Distribution:* It includes:

- Measuring relative effectiveness of different types of distribution intermediaries;
- Measuring dealers' reaction to the firm;
- Measuring warehouse efficiency.

f) *Research on Pricing:* It includes:

- Assessing the general pattern of pricing followed by the industry;
- Evaluating the pricing strategy of the firm;
- Measuring price elasticity of demand.

g) *Research on Sales Methods:* it includes:

- Testing new sales programmes;
- Analysing problems of selling;
- Measuring the effectiveness of salesmen;
- Study of sales compensation.

h) *Research on Competition:* It includes:

- Study on competitive structure of the industry;
- Study on the competitive structure of the individual competitor;
- Study of competitor's product, prices;
- Study of the competitor's promotion programme, channels policies, etc.

Steps involved in marketing research

The researchers have to go through several steps in order to apply marketing research to solve any marketing problem. The major steps are as follows:

1. *Defining and Analysing the problem:* The marketing problem should be clearly identified and defined. If the definition of the problem is faulty the research results will be misleading e.g. research should be conducted to analyse the effectiveness of advertisement.

2. *Developing a research design:* After the marketing problem has been clearly defined, the researcher should develop a proper research design. He should decide on how to collect data, the various research instruments to be used, sampling plan etc.

3. *Collection of data:* Data is the foundation of all marketing research. Data can be primary data or secondary data.

   Primary data is the data collected by the researcher himself and that too for the first time. It can be collected through salesmen, dealers, consumers etc. The researchers can also refer to the reports like sales turnover reports, advertising reports etc. The important reports can be collected through various research instruments like tape recorder, cameras, questionnaires, telephone interviews, e-mails etc.

   Secondary data is the data collected earlier by some other agency or body and used by the researcher. It can be gathered through magazines, journals, government publications, annual reports of companies, etc.

4. *To analyse the data collected:* The next step is to extract meaningful information from the data collected. It can be done through:

   - Averages;
   - Measures of dispersion;
   - Measures of correlation and co-efficient of variation;
   - Goodness of fit.

5. *Report preparation and implementation:* This is the last step in the research procedure. The major findings and recommendations, which are inferred from the study, should be properly prepared.

The findings should be written in concise, succinct simple and clear language. It can be supported with graphs, tables and examples .It should then be properly presented, thoroughly discussed and decision should thereafter, be taken rationally.

Activity

You are required to fill the following questionnaire after interviewing at least 5 consumers regarding their tastes and preferences in respect of consumption of potato chips. You may use Photostat copies of the questionnaire.

1. Name:
2. Age:
3. Sex: ☐ Male ☐ Female
4. Address:
5. Questions:

   ☐ Self-employed ☐ Housewife

   ☐ Govt. employee ☐ Private Sector employee

   ☐ Student ☐ Any other, Specify____

6. Monthly Income:

   ☐ Below Rs. 5,000 ☐ Rs. 5,000-10000

   ☐ Rs. 10,000-15,000 ☐ Above Rs. 15,000

7. Do you consume potato chips? If yes, how frequently:

   ☐ Less than 3 days in a week

   ☐ Between 3-5 days in a week

   ☐ Above 5 days in week

8. Which flavour of potato chips do you like most?

   ☐ Plain salted flavour ☐ Chilly flavour

   ☐ Masala flavour ☐ Tomato flavour

9. How much importance do you give to a brand while asking for a packet of potato chips?

   ☐ Quite a lot ☐ Medium

   ☐ Not much

10. Which brand of potato chips do you like the most? (Rank your preferences):

    ☐ Ruffle Lays ☐ Uncle Chipps

    ☐ Cheetoes ☐ Haldiram

    ☐ Any other, Specify_______________

11. What aspect do you consider most while choosing potato chips?

    ☐ Brand name ☐ Quantity

    ☐ Taste ☐ Price

    ☐ Colour of the Pack ☐ Free gift inside the pack

    ☐ Advertisement of the manufacturer

2) Standardisation and grading

a) *Standardisation:* Standardisation means production of such goods as will be uniformly of the same specifications with regard to shape, size, colour, material, performance etc. If the goods are not standardised it will have a negative impact on the minds of the consumers. The customers will lose faith and trust in the product and may shift to an other brand. The uniform specifications should be such that the customer is not required to examine the product each time before purchasing it.

b) *Grading:* Grading is division of product into classes made of units possessing similar features of size, shape, colour and quality. Grading is usually done in raw materials and agricultural products. For example, rice, wheat pulses, fruits, vegetables, eggs etc. are graded.

3) Financing

The role of finance in any business cannot be under-estimated. Finance acts as a lubricant, which makes the wheels of business move faster and faster. Finance is required for marketing the various goods and services. A businessman may need finance for short-term purposes or long-term purposes. Short-term purposes may include paying salary to salesmen or paying expenses on conducting surveys etc. Long-term purposes may include purchasing of computers or constructing a godown or purchasing vehicles for delivering goods etc.

The various sources of finance are:

- Own Capital
- Friends and relatives
- Commercial banks
- Co-operative banks
- Agricultural credit societies
- Government agencies etc.

4) *Risk taking*

Business risks refer to the possibility of inadequate profit or even losses due to unexpected events, which are beyond control. Risk is part and parcel of business. There are plenty of risks involved in any business. Risks arise due to unforeseen circumstances, natural calamities, wrong planning, irresponsible human behaviour etc. An enterprise has to bear innumerable risks in the process of marketing goods and services. Some of the examples are as below:

- Risk due to fire
- Risk due to theft and negligence
- Accidents
- Change in government policies
- Drought, famine, lightning and earthquakes
- Wrong estimation
- Change in tastes and fashion
- Technology changes
- Trade cycle risks etc.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Give one word for the following:

   i) A process of transferring of ownership of the product from seller to the buyer.

   ii) Movement of men and material from one place to another.

   iii) Activities involved in helping the process of exchange.

   iv) A place where storing is done.

   v) Possibility of losses due to unforeseen circumstances.

2. Match the following:

Type of product	Mode of transport
1) Logs of wood	A) Air plane
2) Imported Fruits	B) Elephants
3) Coal	C) Water
4) Wood-planks	D) Train
5) Sugar bags	E) Lorry

3. Give two examples for each of the following:

   i) Products which can be graded;
   ii) Short-term finance required;
   iii) Primary Data (source)

iv) Research instruments;
v) Means of Road transport.

i) …………………………………………………………………………...

ii) …………………………………………………………………………...

iii) …………………………………………………………………………...

iv) …………………………………………………………………………...

v) …………………………………………………………………………...

4. Warehousing is important because:

i) …………………………………………………………………………...

ii) …………………………………………………………………………...

iii) …………………………………………………………………………...

5. What kind of research can be done on products and consumers? Mention two points each.

Products:

i) …………………………………………………………………………...

ii) …………………………………………………………………………...

Consumers:

i) …………………………………………………………………………...

ii) …………………………………………………………………………...

6.3 WHAT IS MARKETING MIX?

The business firm usually develops a marketing plan to achieve its various marketing objectives. Developing a plan is becoming more and more important keeping in view the ever expanding global scenario, tight competition, changing needs and wants of the customers, technological changes etc.

Marketing mix is a plan designed to analyse the marketing problems. In fact, marketing mix is the ingredients or variables, which the marketer mixes in order to interact with a particular market.

Marketing mix is the term used to describe the combination of four inputs, which constitute the core of a firm's marketing programme. The four areas are as follows:

- Product Mix
- Price
- Place (Distribution)
- Promotion

These are popularly known as four P's of marketing mix (Figure 6.4).

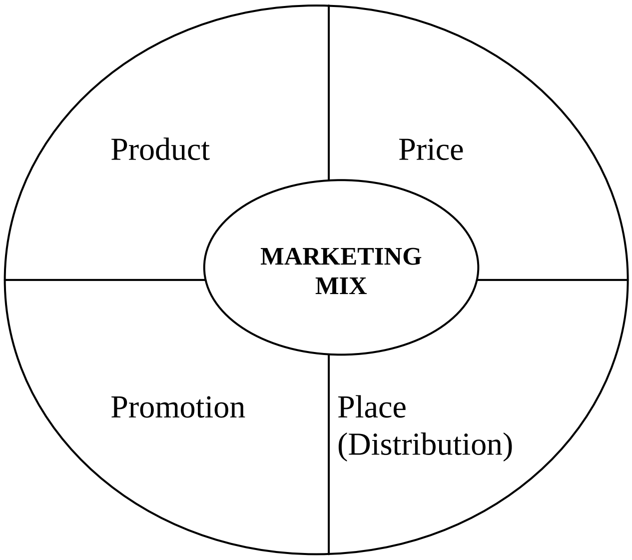


Figure 6.4: Diagrammatic presentation of 4 p's of marketing mix

The idea behind development of a marketing mix is to have greater consumer satisfaction. Marketing mix refers to various decisions taken in the context of product, price structure, promotional activities and the distribution system. A bird's eye view of these decisions, being sub-elements of 4 P's of marketing mix, is depicted in Figure 6.5.

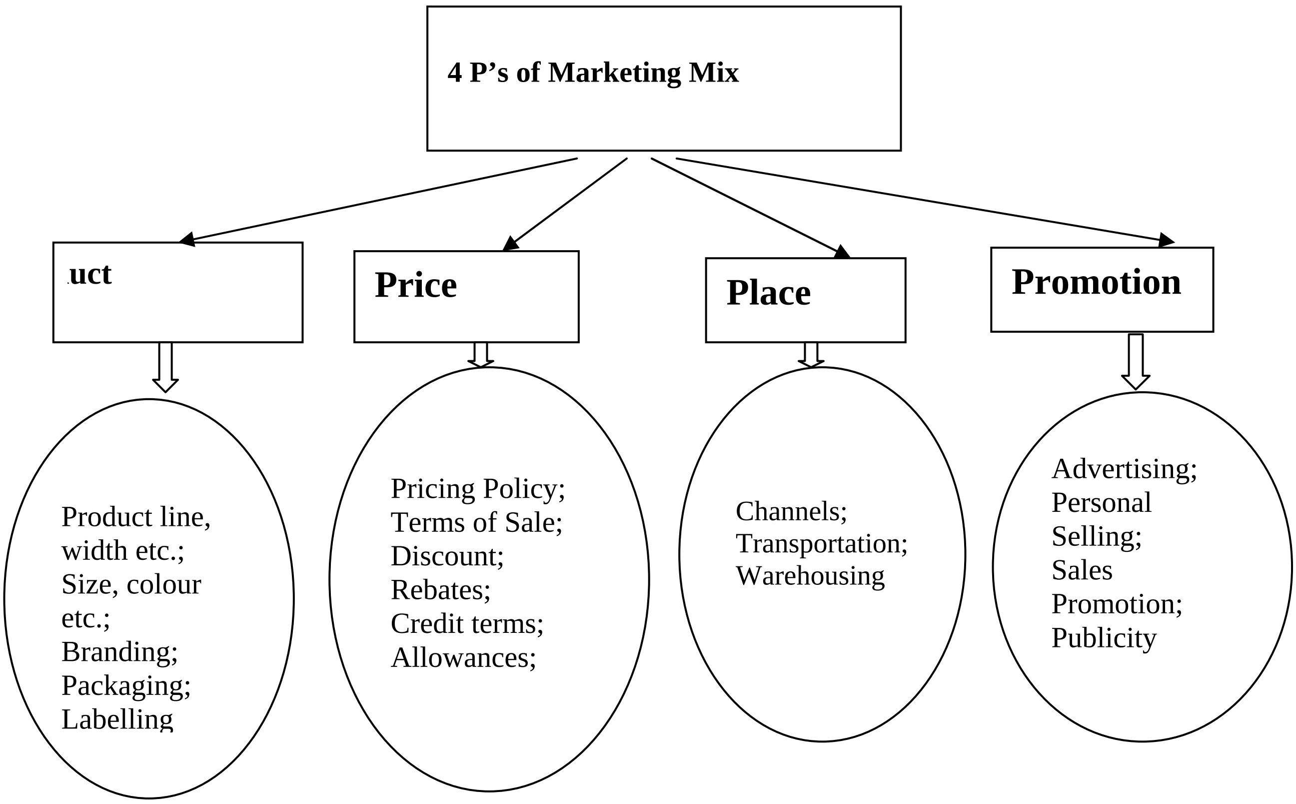


Figure 6.5: Chart showing 4 p's of marketing mix with their sub-elements

Let's explain the above-mentioned P's of marketing in the subsequent paragraphs.

6.4 MARKETING MIX – PRODUCT

Product mix refers to a combination of various features relating to the product or service to be offered for sale. It also refers to total number of products and items a businessman offers to the market. But, what is a product?

Product has a very special position in the marketing mix of a firm.

Product in the narrow sense: In this sense, the term 'product' denotes a physical commodity – a mere non-living object. The needs of the consumers are satisfied by using these products. These products can be designed as a need-satisfying entity e.g. a bottle of Kissan's orange squash; a packet of Amul's butter; a Cadbury chocolate bar etc.

Product in the wider sense: In this sense, a product is something more than a mere assemblage of matter. It takes into account the brand name, package etc. that go into the personality build up of the product. It is a source of providing material social and psychological benefits to the customers.

People derive satisfaction from the non-utility aspect of the product as well e.g. Kellogg flakes are consumed to satisfy hunger needs in the morning; but it is also used because of its brand name, packaging, prestige etc. A person feels that he has a better standard of living in consuming flakes manufactured by Kellogg's than by a local company.

Do not all of us get attracted to buy potato wafers of 'Uncle Chipps' than purchasing any other local product? Therefore, it can be said that 'product' is the total package of benefits, which the customer receives when he buys it.

Sub-elements of product mix

Various sub-elements of product mix are discussed below:

I. The nature of product

The nature and characteristics of the product which are contained in the mix are related to:

a) *Product Line:* It refers to a group of products within a product class e.g. in the case of Amul Co-operative Society, butter constitutes one product line, cream constitutes another, milk, a third one; and so on.

b) *Product width:* The width of the product mix denotes the number of product lines that the businessman offers to the market. For example, Amul has a wider product mix whereas MDH has a narrow product mix.

c) *Product length:* It refers to the number of product items that are carried in a product line. The length of product line denotes the number of items in the line e.g. Amul carries a number of product items in a butter line – it offers 'white butter' and 'salted butter'. Similarly Amul cheese may be 'cheese spread', 'sliced cheese'.

d) *Product Depth:* It refers to the total number of variants that are offered in each product item in the product line. In the case of Hindustan Lever Limited, the soap Lux may be Pink, white or Lux international.

II. *Features of a product*

The decisions regarding features of a product are mentioned below:

- *Size:* The size of the product should be easy to handle. It should be convenient to carry. For example, pack of Cadbury chocolate comes in manageable size.

- *Colour:* The colour of the product should be appealing. For example, the yellow colour of Brown & Polson custard.

- *Flavour:* The flavour of the product should have a wide variety of flavours: Priya Gold Biscuits are found in many flavours – pine-apple, elaichi, orange etc.

- *Weight:* A product should not be too heavy. For example Saffola oil comes in one litre pack, Amul butter comes in 100 gms. pack.

- *Durability:* A product should have a longer shelf life. For example Kissan tomato puree has a shelf life of 12 months.

- *Shape:* Solid products can be round (like Milk Bikis cream biscuits manufactured by Britannia); square (like Krack jack biscuits of Parle); rectangle (like Cadbury's Five Star chocolate) etc. In the case of liquid eatables they can take the shape of their containers. For example Pepsi, Coke, Kissan sauce, Kanodia Mustard oil etc.

III. *Branding*

A brand is a name, term, sign, symbol, or design or a combination of them, which is intended to identify the goods or services of the seller and to differentiate them from those of other competitors. A brand distinguishes a product from similar other offerings. A successful brand is a major asset for a company.

- *Brand Name:* It is that part of a brand which can be vocalized or uttered e.g. Five star chocolate, coca-cola, etc.

- *Brand Mark:* It is that part of a brand that can be recognised. It is not utterable since it is in the form of symbol; design etc. e.g. Nestlé's 'Nest' or Mother Dairy's 'Drop'.

- *Trade Mark:* When brand is given legal protection, it is called 'trade mark'. A trade-mark is a legal term protecting the seller's exclusive rights to use the brand name or brand mark. R in circle (i.e. *®)* is used to show that the trademark is registered.

Examples of branding

(To be scanned – Please refer Hard Copy)

Benefits of branding

- The customers find it easier to identify and handle the product.
- It gives the assurance of quality to the customers.
- Less time and energy is wasted in shopping because the customer has to just go to the market and name the brand. Thus, it makes shopping easier.
- A Purchase of a socially visible brand gives immense psychological satisfaction to the buyer.
- The quality of the product may also improve due to competition.

Selecting a brand name

Following aspects should be taken into account while selecting a brand name:

- It should reflect some benefit and functions of the product e.g. Good Knight, a mosquito repellent suggests that one can have a good sleep at night without mosquitoes.
- It should be distinctive. It should portray status, power etc e.g. Badshah Masale; Everest spices; Shakti-bhog Atta.
- It should be easy to pronounce and remember e.g. Taj Mahal Tea, Jagat Basmati rice.
- It should be legally protected.

IV. Packaging

Packaging may be defined as all the activities involved in designing and producing the containers or wrappers for a product.

Material used in packaging

- Wooden Boxes – Fruits
- Metal Containers – Processed food, oil
- Plastic – Rice, Ghee, Chocolate,
- Paper – Toffees
- Glass – Coke, Jam, Sauce
- Aluminium (foil) – Tea, Coffee

- Jute Sacks – Rice, Wheat
- Tetra pack – Fruit juices, Fruit drinks
- Durable rubber tanks and drums (made from high tenacity polyamide plastic matrix) – Food grains, oil

Forms of package/container

- Tube – Fruit Jelly
- Bottle – Cold Drink
- Small unit package (200 gm, 50 gm) – Tea, Spices
- Sachets – Candy, soups, pan masala
- Re-usable containers (Jars) – Desi Ghee, Edible oil
- Refill packs – Coffee, Chocolate powder, Tea

Benefits of packaging

- It helps in keeping the product safe from pests, rodents, moisture, rain etc.
- It helps in storage.
- It helps in product differentiation.
- It helps in increasing sales.
- It increases the shelf life.
- It ensures visibility of the product if the packaging is transparent.

Activity

Match the following:

Type of package	Product
1. Tetra pack	A) Kissan Jam
2. Glass	B) Frooti
3. Plastic	C) Pineapple Slices
4. Tin	D) Rice

(**Hint:** 1. B; 2. A; 3. D; 4. C)

V. Labelling

The term labelling means putting labels on the package or the product. A label is a small slip to provide information to the customers e.g. the name of the product, price etc. A specimen of labelling is given below:

(Specimen of Labelling*)

Functions of labelling

Labelling serves the following functions:

- Identification of a product is easy for the customer.
- The manufacturer is able to grade the products into different categories, e.g. Hindustan Lever Limited (HLL) sells different types of tea under yellow, red and green label.
- It is a carrier of information.
- It provides information, which is mandatory by law.
- It attracts the buyers and draws them to buy the product.

6.5 MARKETING MIX – PRICE

Pricing is one of the most important decision-area of marketing. This is the only area from where revenue is earned by a businessman. Pricing is crucial to profit as well. Price is the exchange value of a product.

Factors influencing pricing policy

- *Consistency:* Pricing has to be consistent with overall objectives of the firm, e.g. the firm's objective may be profit maximization or to achieve a high turnover. Accordingly, it may be a higher price or lower price.
- *Public image:* If the public image of the product is high the price may be kept high.
- *Purchasing power of the consumers*: If the purchasing power of the consumers is low, the price should be kept low.
- *Price control measures:* The prices of certain products are controlled by the government. The businessman should fix the price keeping in mind the prevailing policies of the government.
- *Pricing policy of the competitors*: The businessman should fix the price keeping in view the pricing policy of the competitors.

* (The sample has been used for educational purpose only and not for any other use).

- *Availability of substitutes:* The price may be kept higher in case there is no substitute available in the market.
- *Ability to postpone purchase:* If the consumer can think of postponing the purchase of a particular product the price of such product should be kept low.
- *Cost of production:* The price fixed should be such as would recover all the costs including a fair return to the businessman.
- *Demand and Supply:* If the demand of the product is higher than its supply the price may be fixed at a higher level. In case supply exceeds the demand, the price should be fixed al low level.
- *Current fashion and tastes:* If the product matches the current fashion and tastes, a high price may be fixed.

Decisions regarding terms of sale

The terms of sale, which the businessman may decide, shall include the following:

- Ex-works price
- Ex-warehouse price
- Cash sale price
- Credit sale price
- Instalment facility etc.

Decisions regarding discounts and rebates

The businessman, keeping in view the trends of business, may offer certain types of discounts and rebates. The may include:

- Trade discount
- Cash discount
- Off-season rebate
- Festival rebate
- Rebate for cash down purchase etc.

Activity

In the following Table two brand names of five products are given. Visit a local grocery shop; enquire about the MRPs of these products and on that basis fill the column relating to MRP.

Product	Brand/ Company	MRP	Brand/Company	MRP
1. Jam	Tops		Kissan	
2. Milk	Mother dairy		Parag	
3. Edible Oil	Dhara		Saffola Gold	
4. Biscuits	Parle G		Priya Gold	
5. Bread	Britannia		Harvest	

6.6 MARKETING MIX – PROMOTION

Promotion of the product is another important element of marketing mix. Marketing depends heavily on effective communication flow between the business firm and the consumer. It involves informing the potential customers about the availability of product and stimulating them to buy it. The businessman usually chooses a combination of communication effects. This is called development of communication mix.

The following are the communication tools (or promotional measures), which a seller can follow:

a) Advertising

b) Sales promotion

c) Personal selling

d) Publicity

A combination of these techniques is used by the businessman depending upon the nature of the product, type of customers, degree of competition, etc.

a) Advertising

Advertising is a potent promotional tool of marketing communication. It is any paid form of non-personal presentation and promotion of ideas, goods or services by an identified sponsor. The businessman tries to spread his ideas about his product among his customers through advertising.

Benefits of advertising (for consumers)

- It provides information regarding price, availability, quality etc.
- Comparison with other products becomes easier.
- It acts as a guarantee regarding quality.

Benefits of advertising (for manufacturers)

- It increases the sale of the product.
- It helps in easy introduction of new product.
- It establishes contact between manufacturers and consumers.
- It helps build the image of a product.
- It enables them to face competition.

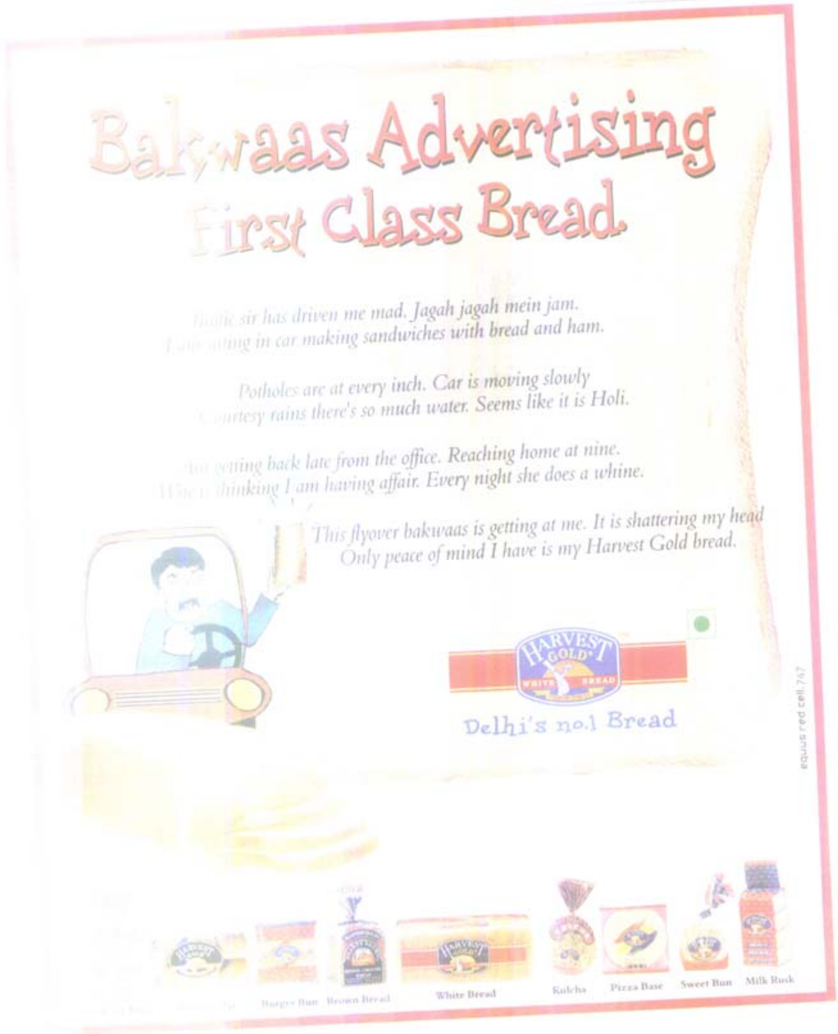
Media of advertising

The following Table shows the various kinds of media of advertising, which a manufacturer may resort to.

Print media	Electronic media	Outdoor display	Direct mail
Newspapers	TV	Bill boards	Price list
Direct mail	Video	Hoardings	Catalogues
Folders	Radios	Balloons	Letters
Journals	Cinema	Electric poles	Circulars
Magazines	Internet	Fairs and exhibitions	Pamphlets

Examples of good advertisements

1. Harvest Gold Bread
2. **P** mark Sarson Oil
3. Balrampur Chini



(Advertisement No.1*)

* (The sample has been used for educational purpose only and not for any other use).

(Advertisement No.2*)

Activity

Scan your environment and write the method of advertising used by the following companies to advertise their products:

* (The sample has been used for educational purpose only and not for any other use).

Company/Brand	Media
1. Horlicks	
2. Pepsi	
3. Badshah Masala	
4. Heinz Tomato Sauce	

b) *Sales promotion*

Sales promotion is an effort to stimulate consumers to purchase more and more of a particular commodity. It draws quick response from the target audience. It serves as a short-term incentive.

Various means of sales promotion (At consumer level)

Following are the various means of sales promotion at consumer level:

- Distribution of free samples
- Organisation of various contests
- Offer of refund of money if the product is not up to the satisfaction
- Offer of free gifts along with the product
- Offer of discounts and rebates
- Offer of quantity deals like 'buy two get one free'
- Demonstration
- Instalment payment

c) *Personal selling*

It is the oldest method of selling a product. It means selling personally. It is oral, face-to-face interaction between a seller and prospective customers for the purpose of making sales. It leads to 'on the spot sales'.

The salesman usually goes door to door, presents and demonstrates the product and tries to negotiate a deal. He also acts as a guide as he informs about the product.

A well-trained and competent salesman can be an effective communication instrument. His knowledge about the product, the company, its future plans, familiarity with customers, level of his motivation will be the determining factors in his role as a communicator.

d) *Publicity*

Publicity is not easily controllable by the firm. It is not paid for by an identified sponsor. Large firms normally try to control, through constant press releases, press conferences etc. Such activities are intended to build a favourable and positive public image of the firm but an adverse message appearing in some media about a product may spoil the image of the company.

6.7 MARKETING MIX – PLACE (DISTRIBUTION)

Place mix involves decisions to be taken in order to make the product available to the customers. Two decisions are required to be taken for this purpose:

1) *Development of channels of distribution*

   Channels of distribution refer to the path taken by the goods in their movement to the customers. It starts with the producer and ends with the consumer. In between there may be a network of inter-dependent organisations or people employed like agents, dealers, wholesalers and retailers, which help in the transfer of product.

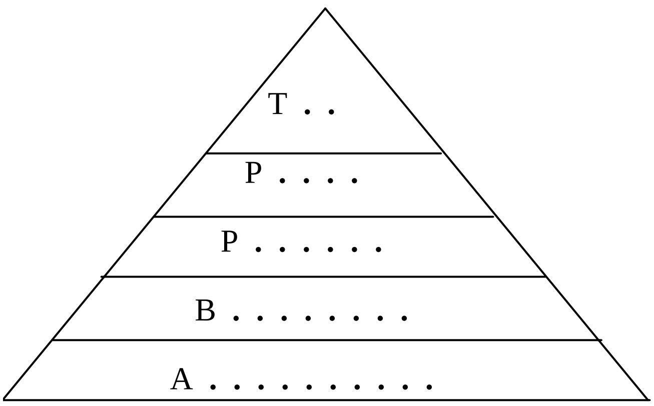
2) *Physical distribution of product*

   Physical distribution involves physical handling of movements of goods from place of production to the place of consumption. Physical distribution fills time (through warehousing) and place (through transportation) gap by providing goods at right place, at right time in the right condition and lowest possible cost.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. On the basis of the given clues fill the following pyramid:



Clues:

i) A package material (3 letters)

ii) Exchange value of a product (5 letters)

iii) A carrier of physical and psychological satisfaction (7 letters)

iv) Assigning name to a product (8 letters)

v) A paid form of non-personal presentation and promotion of goods (11 letters)

2. List the 4 P's of marketing mix.

   i) ……………………………………………………………………...

   ii) ……………………………………………………………………...

   iii) ……………………………………………………………………...

   iv) ……………………………………………………………………...

3. You are a manufacturer of Bikaneri Namkeen. You want to appoint a salesman for door-to-door selling of the product. Name two qualities, which he should possess in order to be a good salesman.

   i) ……………………………………………………………………...

   ii) ……………………………………………………………………...

4. Name the oldest method of selling products.

   ……………………………………………………………………........

   ……………………………………………………………………........

5. Name the non-paid form of communication tool.

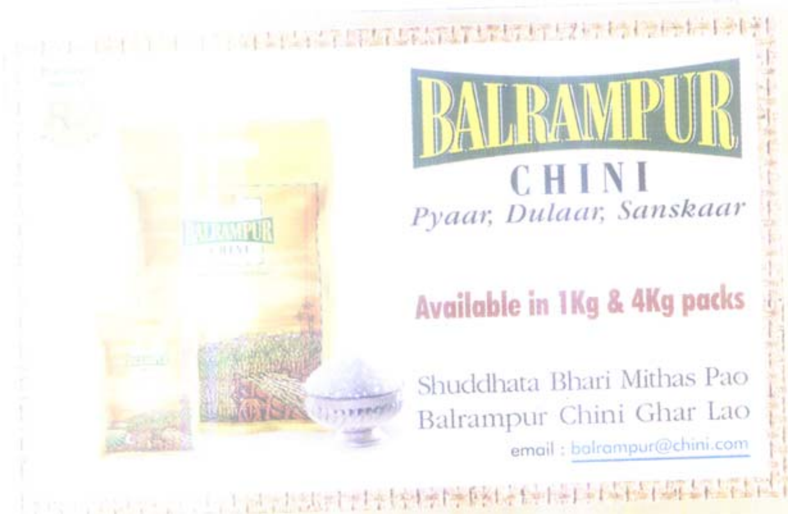
   ……………………………………………………………………........

   ……………………………………………………………………........

6. Observe critically the following advertisement and comment on the basis of information provided in the advertisement whether:

   i) it is attractive to you as a prospective consumer.

   ii) it contains complete information about the product.



(Advertisement No.3*)

6.8 LET US SUM UP

Marketing is the central function of any business. The entire business is a customer satisfying process. Marketing enables a businessman to sell his goods to the consumers. The functions of marketing may be broadly categorised as functions of exchange; functions of physical supply; and facilitating functions. The functions of exchange involve activities associated with buying; assembling and selling. The functions of physical supply include transportation; storage (also called warehousing); inventory management; and order processing. Facilitating functions refer to the activities involved in helping the process of exchange. Important facilitating functions include marketing research, standardisation and grading, financing and risk taking. Marketing mix is a plan designed to analyse the marketing problems. The four areas of marketing mix, known as 4 P's, are product mix, price, place (distribution) and promotion. Product mix involves decisions involving product line, product width, product size, its colour, branding, packaging, labelling etc. In the case of price mix the businessman takes decisions relating to pricing policy, terms of sale, discount, rebates, credit terms, allowances etc. Decisions regarding channels of distribution, transportation, warehousing etc. are related to place mix and finally promotion mix involves decisions regarding advertising, personal selling, sales promotion, publicity etc.

6.9 KEY WORDS

Ex-works price	:	Factory price.
Inventory	:	Stock of goods
MRP	:	Maximum retail price.
Price elasticity of demand	:	Ratio of the percentage change in demand caused by a percentage change in price.
Trade discount	:	Discount allowed by a trader when goods are purchased in bulk quantity.
Warehouse	:	A place where goods are stored.

6.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. i) Buying ii) Transportation iii) Facilitation

* (The sample has been used for educational purpose only and not for any other use).

iv) Warehouse v) Risks

2. 1) B 2) A 3) D 4) C 5) E

3. i) Rice and wheat;

   ii) For purchase of raw material; payment of salary;

   iii) Consumers and Dealers;

   iv) Questionnaires; E-mails;

   v) Trucks; Bullock Carts.

4. **Hint:** i) Storage of goods;

   ii) Bulk purchase or manufacture of goods;

   iii) Adjustment of supply with demand.

5. **Product:**

   i) Reviewing product line, product quality, Product features etc;

   ii) Testing of new products.

   Consumers:

   i) Study of the consumer tastes;

   ii) Study of consumer dissatisfactions.

Check Your Progress Exercise 2

1. i) Tin

   ii) Price

   iii) Product

   iv) Branding

   v) Advertising

2. i) Price ii) Product

   iii) Promotion iv) Place

3. i) Understanding about the product.

   ii) Motivation to do hard work.

4. Personal selling.

5. Publicity.

6. **Hint:** Look at the advertisement critically and answer accordingly.

6.11 SOME USEFUL BOOKS

1. Bhushan, Y.K. (2005) Fundamentals of Business Organisation and Management; Sultan Chand and Sons, New Delhi.

2. Kotler, Philip (2004) Marketing Management – Analysis, Planning and Control, Prentice Hall of India, New Delhi.

3. Varshney, R.L. and Gupta, S.L. (2000) Marketing Management (An Indian Perspective); Sultan Chand and Sons, New Delhi.

6.12 ASSIGNMENTS

1. "It pays to advertise" Justify.

2. Explain how a businessman can promote his sales.

3. "Victoria Foods" have diversified and started processing and packing 'light oven baked porridge (Dalia)'. You are the marketing manager of this firm. What factors will you keep in mind to decide the price of this product?

4. "Bhojan India" wants to transport 50 cartons of 'White wheat Flour' from Chandigarh to Delhi. Which means of transport should they use and why?

5. 'A warehouse serves the function of protecting goods'. Do you agree? Give reasons in support of your answer.

6. What should a businessman do after receiving orders from a customer?

7. How is marketing research done?

8. What are the features of a good brand?

9. Name the material, which a businessman may decide to use for packaging the following products:

   a) Apples

   b) Mango juice

   c) Roasted chana

   d) Mustard oil

   e) Cookies

10. "A good package acts like a silent salesman". Justify this statement on the basis of following specimen of a package.

(Advertisement No.4*)

* (The sample has been used for educational purpose only and not for any other use).

UNIT 7 ANALYSING THE COMPETITIVE SITUATION

Structure

7.0 OBJECTIVES

After studying this unit, you should be able to:

- get a clear view of the competitors who are posing competition in the market;
- comprehend the strengths and weaknesses of the competitors;
- understand the market strategies a businessman is required to develop;
- know about the SWOT expand analysis; and
- understand the special features of the product which makes it attractive.

7.1 INTRODUCTION

You will note that in today's world, every individual is running a race to achieve a certain goal. All of us are in a hurry – either in search of a goal or to reach a goal before anybody else reaches there. In this process, every one has a desire to excel and be at the top. In this era of technological advances and higher levels of mass communication, followers have no place. Respect, prestige and power are only with the leader.

The child who is awarded the prize is the one who gets first rank in the class. The students who get admissions in prestigious colleges are those who find place in the merit list. The same is the case with a businessman too. They are also busy running a race. Some may have won and reached the top whereas there are others who are trying to reach the coveted place. But, what is that coveted place, the destination. It is the hearts of their customers.

(*Competition:* Racing for No. 1 Position to become Market Leader)

It is only when a businessman satisfies his customers and makes them happy and loyal he will slowly and gradually achieve the maximum share of his target market. And the day may come when he will be Rank 1 holder, being adjudged as “market leader”.

But, do you think, in this process of capturing the market share, other followers (i.e. Rank 2, Rank 3, Rank 4 and so on) will keep quiet? No! They will not sit back and see another capturing the market. They will think of various strategies to beat the Rank 1 who has been adjudged as “market leader”. But the game will not stop at this stage. Now, the Rank 1 will make his counter moves to retain his position in the market. Thus there will be moves and counter moves and the players in the market (i.e. various businessmen) will always think of new strategies to defend themselves or confront competition.

7.2 COMPETITORS PRESENT IN THE MARKET

Every industry – whether it is automobiles, textiles, iron and steel, pharmaceuticals, chemicals, or food processing industry – is composed of many firms dealing in the same product. Usually competition prevails within one industry and each firm has to face stiff competition from the others. They compete with each other to gain the top slot, by achieving maximum share of the market as:

1. Market leader

A market leader is the one, who has reached the place where others want to reach. In a way he has gained maximum share in the relevant product market. It leads the other firms in price changes, new product introduction, distribution coverage etc. For example, there are 4 firms in a particular industry with the following market share:

Firm A	60%
Firm B	25%
Firm C	10%
Firm D	5%

Here, Firm A is the market leader with 60% share in the market.

For other businessmen, the market leader acts as a competitor because his strategies and moves will have a direct impact on the turnover and profits of the other firms. Though competition will not be very severe because it will be quite difficult for other firms to confront and attack the market leader by taking advantage of his weakness, if any.

2. Market challenger

The firm that occupies a place next to the market leader in an industry is known as market challenger or runner-up. There may be one such market challenger or more than one. These firms are also very large but smaller than market leader.

Market challengers are a threat to both the market leader and the other competitors. They would try to grab further market share by directly attacking the leader or by attacking other competitors, if not the market leader. For example, there are 4 firms in a particular industry with the following market share:

Firm A	40%
Firm B	35%
Firm C	15%
Firm D	10%

In the above case Firm B is the market challenger. It can easily become a market leader by grabbing only five or six percent of the share from the market followers or 3% from the leader. Market challenger tries to discover the weaknesses of small firms and of the market leader and then builds up its own strategy.

3. Market followers

Market followers are usually small sized firms. They have lower market share than the leader and the challenger. They are actively trying to expand their share through highly aggressive tactics. All the firms who fall in this category act as rivals to one another. They face a threat from the market challenger who is always keen to gobble up some of their share. They have somehow to hold on to their current customers. All the firms coming in this category occupy almost similar position in the market. They may also have similar resources and similar output. For example, there are 4 firms in a particular industry with the following market share:

Firm A	40%
Firm B	35%
Firm C	15%
Firm D	10%

In the above case Firms C and D are the market followers. Both the firms are acting as rivals to one another to retain the existing share. Both have a threat from the side of market challenger i.e. Firm B who is always keen to gobble up part of their share to become market leader. Even market leader may also try to gobble up party some more of the market to make its position more secure against the market challenger.

4. New entrants

A new entrant is one who has just stepped into that industry. This business unit acts as a source of direct competition to the firms which are already in the business. The new entrant can be a resourceful business unit which has entered a new industry because of its expansion and diversification policies. This new entrant may be a leader in his own field.

5. Very small firms

These firms are very small in size. They cannot attack the larger firms. They earn profits from customers, geographic area, or service.

6. Powerful suppliers

When the businessman acts as buyer in the market he must understand the market power of the different suppliers. There may be powerful suppliers in the market. They are so large and powerful that they are in a position to dictate the price and the terms of supply. The power of the suppliers is high when there are very few suppliers in the market. And therefore the businessman has limited option for source of supplies. He will compete with other similar purchasers and will have to put efforts to acquire the supplies at a reasonable price and as per his requirements – quality, time, and quantity etc.

7. Powerful buyers

Similar to powerful suppliers there may be powerful buyers in the market if it is a 'buyers market". Since these buyers are big and powerful they will dictate their prices, terms of purchase, their preferences for packaging, product quality, and delivery terms.

8. Substitute products made available by other competitors

The product supplied by the businessman is to be considered in the light of uniqueness. He has to see whether his product is unique or there exists any substitute for the same. It may also happen that at a later stage a substitute may arise. In case the substitute is or arises later the businessman will have to see how he is to protect his market and customers.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Who is market leader?

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2. Which kind of competitor is usually called a runner-up?

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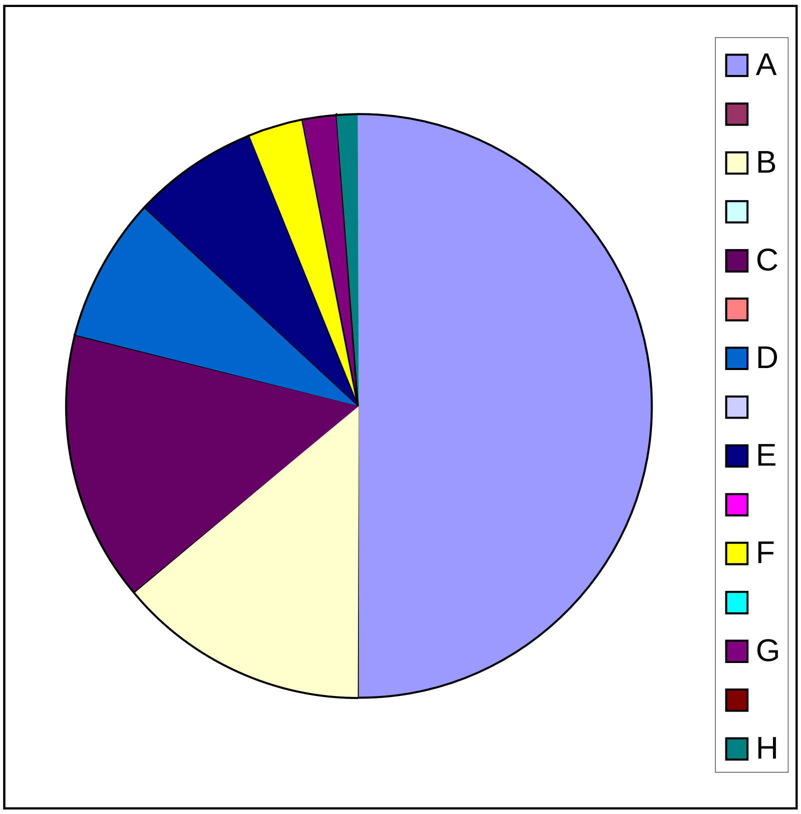
3. Following is the hypothetical market share of the various firms:

A) 50%; B) 14%; C) 15%; D) 8%;

E) 7%; F) 3%; G) 2%; H) 1%

Fill in the blanks after analysing the following pie diagram which depicts the market share of above firms:



i) ------------------ is the market leader.

ii) ------------------ are the market challengers.

iii) ------------------ are the market followers.

iv) ------------------ are the small firms.

7.3 MARKETING STRATEGIES VIS-À-VIS COMPETITORS

The businessman has to develop his marketing strategies on the basis of the activities of his competitors. Following are the areas/activities in which the businessman can develop his marketing strategies:

i) Innovations

To beat the competitors the businessman can decide to launch a new product. He can also think of innovative ideas related to customer service, means of distribution etc.

ii) *Prices*

The businessman can keep the prices of his products reasonable in comparison to the price structure maintained by his competitors. At times, the businessman may reduce the prices as well. However, a fear of price war is always associated with this kind of strategy.

iii) *Promotional strategies*

The businessman can adopt promotional strategies by offering discounts, organizing contests, providing free gifts etc. to the customers. But this will also mean sizeable promotional expenditure.

iv) *Quality strategies*

Continuous efforts can be made to improve the quality of the product. At times, we find a slogan 'New and Improved' printed on the package of the product. This is nothing but to beat the competitor that firm's product is now improved as compared to that of the competitor. The firms, now-a-days spend a lot on research and development (R & D) activities. The expenditure is incurred with a view to improving the quality of the product.

v) *Product size*

The businessman can make additions in the size and form of his product. In other words he can bring a product in several sizes and forms, which his competitors may not be having. For example, a ketchup manufacturer may plan to bring his product in many innovation or quality and bottle sizes.

vi) *New brand*

A businessman may launch a new brand of the same product. Each of the brands can be positioned differently in the minds of the consumers.

vii) *Heavy advertisement*

The businessman can undertake heavy advertisement campaign. This will help him to create strong consumer awareness and preferences.

viii) *Competent sales force*

Manpower is an asset for any firm. A good and confident sales force maintained by a businessman may fetch him reputation, good business, loyalty of the customers etc.

ix) *Manufacturing efficiency*

This is another way of facing the competitor. The businessman tries to keep the cost of production low by efficient purchase of material, low labour cost, using modern equipments, etc.

x) *Efficient and extensive dealership system*

A large number of independent dealers can be maintained in the industry. The dealers can be located all over the country and even outside the country also, if the demand arises. An exclusive dealer may focus all of their attention on his product.

xi) Credit policy

In order to increase his turnover in comparison to his competitors the businessman may offer his product on credit terms – instalments, repayment period etc.

xii) Better after-sales services

The businessman may offer better and efficient after-sales service to his customers. A satisfied customer will not only be loyal to him but may bring in more customers through his contacts. Thus, the businessman may expect that the potential customers will not go to his competitors.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What can be the marketing strategy of a businessman in respect to the size of the product?

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2. Mention any four ways by which a businessman can counter-act the activities of his competitors.

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7.4 HOW TO UNDERSTAND THE STRENGTHS AND WEAKNESSES OF BUSINESS

Several functions are carried out in a business enterprise. These are linked with production, research and development, personnel, finance, marketing, etc. The businessman can understand his strength by splitting each function into sub factors. Through this exercise specific factors are identified. Then he tries to zero in on the specific factors, which he can point out and say "Hey, this is my strength".

Business firms have to spot their competitive strengths and nurture them. By studying the competitive strength with respect to the firm's overall strength or weakness in the given area, the firm has to find out – what its distinctive advantages are. For this purpose, internal scanning is to be done. It may relate to –

- Which are the functions the firm does well compared with his competitors.
- Does the firm really excel in them?
- Which are the functions where the firm is weak?
- To what extent does the weakness matter in overall performance?
- Can the weaknesses be made up?

To have a better understanding, the business firm should conduct SWOT Analysis.

SWOT analysis

Just as a doctor needs thermometer or a stethoscope to diagnose an illness, in the same way a businessman needs to do a SWOT analysis to assess the competition he faces in the market. SWOT analysis is an analysis of:

S : Strengths

W : Weaknesses

O : Opportunities

T : Threats

It is a process through which the strengths, weaknesses etc. of a competitor can be assessed. In fact SWOT analysis can be used for any purpose i.e. to evaluate a project; any market opportunity etc.

Strengths: Strengths refers to the strong points a businessman possesses. His strength may lie in the quality of his product or his strategic location or his huge capital base and so on. He should have a firm faith in his internal resources and he should utilise them to their fullest capacity. His strength in a particular area may be the weakness of his competitor.

Weaknesses: The businessman should also always recognise his weak points. He should endeavour to convert his weaknesses into strengths. The weaknesses can be rectified only when they are identified.

Opportunities: There is no dearth of opportunities. The businessman should keep his mind open and make a list of various opportunities, which may be available for him to explore.

Threats: The businessman should be aware of the threats he faces as well. His competitors in the market always pose a threat to him. They may try to divert his customers by offering better product. He should keep on trying to convert the possible threats into opportunities.

In the following way a businessman who is dealing in manufacturing of mango-chutney may conduct SWOT analysis:

S	O
1. Mango chutney goes well with almost every Indian food. 2. Low Investment required for manufacturing chutney.	1. Wide spread market can be captured. 2. Different varieties of chutneys can be introduced.
W	**T**
1. Seasonality of raw material. 2. Seasonality and availability of labour.	1. Presence of a large number of competitors in the market. 2. Tastes of the customers may get changed.

Keeping the points mentioned in the above box (and many more which can be perceived) the businessman has to make continuous efforts to convert his weaknesses into strengths and threats into opportunities to the maximum extent. This way he can thwart competition.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write the full form of SWOT.

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2. How can a business man conduct SWOT analysis?

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7.5 WHAT ARE THE STRENGTHS AND WEAKNESSES OF THE COMPETITORS

Just as an individual has certain strengths and weaknesses, in the same way a business firm possesses certain qualities, which are its strengths and also a few points which are its weaknesses. Big firms generally take the benefit of their size and small firms have the benefit of flexibility and speed of functioning.

The strength of the competitors can emerge in any of the many functions they perform. These functions may be associated with marketing, production, research and development, corporate resources. In the following paragraphs an attempts made to discuss these factors. The presence of these factors may act as strength whereas the absence of these factors may mean weakness.

Product mix

To gain an edge over others, the competitor can shape his product strategy around the technical superiority of his product. The product can be a special product supported by the best technology and its superior quality. He may also be providing attention to quality control and quality assurance. The competitor can be stronger if he has a wide product line. He may also provide maximum possible variety in every product line.

The competitor may also be keeping in mind the tastes and preferences of the customers based on demographic, geographic and psychological factors.

Packaging

The packaging of a product may also serve as a potent strength in the competition. Good packaging adds to the value of the product. An attractive package may lead to increase in turnover. A package contains lot of information as well. It acts as a silent salesman. A good package, therefore, if developed by a competitor may act as a strong point. A new package design, colour, size of the package, material used etc. can all serve as strengths.

Distribution

Some competitors may have a distinctive competence in distribution. They may have a distribution network reaching the remotest rural areas of the country. They may also have a vast chain of showrooms in all metropolitan cities and other big cities of the country. They may have a computerized physical distribution method as well. The other advantage, which the competitors may have, is to have a chain of big stockists who get the supplies directly from the producers. They may also adopt progressive distribution policy, attractive incentives and best margins for dealers.

Service

Providing efficient service to the customers would also be a strength. For example, M/s. A.B. & Co. may assure its customers to provide after-sales service within 24 hours of the receipt of call.

Personnel

A pool of highly talented engineers, technicians and managers and other personnel would be highly motivated and dedicated because of handsome salaries and other perquisites.

Production

A competitor’s strength may lie in the production function. He may come out with large quantity of production within a very short period of time. For example, M/s. Ruchika & Co. may have a high capacity of manufacturing biscuits and other bakery items. Expertise in production planning and scheduling will provide an edge over other businessmen particularly if it matches with the market requirements.

Research and development

This is another area where a competitor may have an edge over the other businessmen. A competitor may possess a competence for making unique products. He may have strong in-house R&D facilities for consistent product augmentation and improvement.

Corporate and finance factor

A competitor may have a reputation in the market. Owing to the goodwill built by him, he is in a position to raise large equity in the capital market. A competitor's strength may also lie in the huge reserves built by his firm. With the help of these reserves he will not face resource crunch when there is depression in the market and it becomes difficult to obtain funds from external sources.

Marketing

A competitor may be well-versed with marketing techniques. His sales forecasting may be very accurate or he may be possessing a highly computerized and high quality Management Information System (MIS). A competitor may be in a position to incur heavy expenditure on advertisement and publicity as well. The price strategy followed by the competitor may be such that it attracts abundance of business.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How can an attractive package lead to increase in turnover of a competitor?

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2. "A competitor's strength lies in his production function." Justify.

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7.6 SPECIAL FEATURES OF THE PRODUCT TO ATTRACT CUSTOMERS

Quality of the product is one major factor on which a businessman can count.

Features of the product

i) *Value for money*

   A businessman should develop his product in such a manner that the customer utilizing it should get value for the money spent by him in purchasing the product. For example, if a customer purchases Britannia Cake, it should give him the value, which he thought he will get if he had spent the same money on some other product.

ii) Tangible attributes

- *Size:* The product should be of such size that it can easily be handled.
- *Colour:* The product should be of attractive colour so that it appeals to the customer at the first look.
- *Weight:* A product should not be too heavy to lift. It may be packed in such a way that the customer is in a position to carry it easily. Usually oils are packed in one Kg./one litre packs.
- *Durability:* Most of the products are not meant for one time use. A customer will prefer a product, which can be used for a reasonable period. In other words the product should contain proper preservatives.
- *Packaging:* The product should be packed in such a manner that it remains safe from pests, moisture, rain etc. A good packaging should help in increasing sales and the packed product can be stored easily.
- *Shape:* The shape of the product should be appealing. It may be round, square, rectangle or any other shape. Liquids will of course eatables they can take the shape of their containers.
- *Branding:* The brand name of the product should be such that the customers will find it easier to pronounce and remember. The customer should easily identify the product with its brand name. It should give the customers the assurance of quality.

iii) Augmented attributes

Some additional features can also be added to the product, like:

- Providing after-sales service;
- Providing various finance options like purchasing goods on instalment basis, purchasing goods on zero interest rate etc.
- Providing delivery arrangement like free home delivery;
- Offering warranties.

iv) Product variety

The businessman should try to offer a number of variants in the product. For example a product can come in various flavours.

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List any four tangible attributes of a product.

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2. Mahesh is a businessman who manufactures mango pickles. Mention any two quality features which he should try to bring in his product so as to make it preferable to those of his competitors.

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7.7 LET US SUM UP

Every individual, be it a businessman or any other person is running a race to achieve the No. 1 position. In case of a businessman, however, it is only when he satisfies his customers and makes them happy and loyal he will slowly and gradually achieve the maximum share of his target market. Market comprises a number of competitors. There may be market leader, market challengers, market followers, new entrants, small firms etc. Powerful buyers, powerful suppliers and substitute products are capable of posing competition. As regards marketing strategies to be adopted by a businessman, they are to be adopted based on the activities of the competitors. To understand the strengths and weaknesses of the business, the businessman is required to carry out SWOT Analysis. He has to try his level best to convert weaknesses into strengths and threats into opportunities. A competitor will pose competition to the businessmen due to the presence of certain strengths. The strength of the competitors lies in the level of their functions (like marketing, production, research and development, corporate resources). To thwart competitors, a businessman has to provide quality products to his customers. There are so many features associated with any product that he has to provide a product which gives value to the purchaser for the money spent in purchasing it. The product should have certain tangible attributes. The businessman may also add a few additional features to the product to make it more attractive than that of his competitors.

7.8 KEY WORDS

Market leader	**:**	A business firm possessing largest market share.
Market challenger	**:**	A business firm posing threat to the market leader.
Tangible attributes	**:**	Features of a product perceptible to the senses – sight, smell and mostly taste.

7.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. **Hint:** Market leader is the organisation which has gained maximum share in the relevant product market.

2. **Hint:** The firm that occupies a place next to the market leader in an industry is known as runner-up.

3. i) *Firm A* is the market leader.

   ii) *Firms B and C* are the market challengers.

   iii) *Firms D and E* are the market followers.

   iv) *Firms F, G and H* are the small firms.

Check Your Progress Exercise 2

1. **Hint:** The businessman can make additions in the size and form of his product.

2. **Hint:** Innovations; Price; Product size; New Brand

Check Your Progress Exercise 3

1. Strength, Weakness, Opportunity, Threat

2. **Hint:** By analysing his Strength, Weakness, Opportunity, and Threat.

Check Your Progress Exercise 4

1. **Hint:** Good packaging adds to the value of the product and thereby an attractive package may lead to increase in turnover of a competitor.

2. **Hint:** A competitor may come out with large quantity of production within a very short period of time.

Check Your Progress Exercise 5

1. Size; Colour; Durability; Branding

2. i) Increased durability of the product.
   ii) Attractive packing.

7.10 SOME USEFUL BOOKS

1. David H. Holt (2002) Entrepreneurship – A New Venture Creation, Prentice Hall of India Private Limited, New Delhi.

2. Ramaswamy, V.S. and Namakumari, S. (1998) Marketing Management (Planning, Implementation and Control – The Indian Context), Reprint, Macmillan India Limited, Delhi.

3. Varshney, R.L. and Gupta, S.L. (2000) Marketing Management (An Indian Perspective), Sultan Chand and Sons, New Delhi.

7.11 ASSIGNMENTS

1. Mention any five points relating to the strengths and weaknesses of the competitors.

2. Read the following situation:

   i) Firm I deals in fertilizers.
   ii) Firm G deals in textiles.
   iii) Firm N deals in cosmetics
   iv) Firm O deals in agro-based products
   v) Firm U is a new entrant desiring to manufacture mushroom soup.

Based on the above, identify the competitor for Firm U. Give reasons in support of your answer.

(**Hint:** Firm O)

3. Radha Food Limited manufactures 'ready-to-eat' products. They want to conduct SWOT Analysis in order to guard against the various competitors some of whom are new entrants. They have appointed you as a new market researcher. On the basis of following jumbled up points you are required to group them in the given Table:

i) 14 year old established company.
ii) Low average perception among consumers.
iii) Entry of MNCs on a large scale.
iv) High competition.
v) Both husband and wife form a working couple.
vi) Status symbol.
vii) Use of latest technology by the company.
viii) Low product range.
ix) Huge Capital and dedicated staff.

S	O
1. 2. 3.	1. 2. 3.
W	**T**
1. 2. 3.	1. 2. 3.

(**Hint:** i) S; ii) W; iii) T; iv) T; v) O;
vi) O; vii) S; viii) W; ix) S)

4. Explain the roles of market leader and market challenger in a competitive market.

5. "The strengths of the competitors emerge from the functions they perform" Do you agree? Give reasons.

6. To what matters would "internal scanning" relate?

7. Following is the hypothetical market share of various firms operating in a particular industry:

Firm A	48%
Firm B	42%
Firm C	5%
Firm D	5%

You are required to answer the following questions:

i) Can Firm D act as a threat to Firm B?

ii) Can Firm B act as a threat to Firm A?

iii) Can Firm B act as a threat to Firm C?

iv) Can Firm C act as a threat to Firm A?

v) Can Firm D act as a threat to Firm C?

vi) Can Firm C act as a threat to Firm D?

(**Hint:** i) No; ii) Yes; iii) Yes; iv) No; v) Yes; vi) Yes)

UNIT 8 PREPARATION OF THE BUSINESS PLAN

Structure

8.0 OBJECTIVES

After studying this unit, you should be able to:

- know about the business plan;
- understand the need for business plan;
- identify various inputs of business plan;
- know the challenges faced during the preparation of business plan;
- comprehend the common errors faced in a business plan; and
- understand how to avoid such errors.

8.1 INTRODUCTION

The term ‘business plan’ consists of two words – business and plan. Business is an economic activity. It is associated with buying, selling and manufacturing of goods with a view to earning profit and making a living. The people who engage themselves in a business are known as businessmen or entrepreneurs. Plan is a course of action to achieve a desired result. To plan is to look ahead. It is to assess the future and make provisions for it. Owing to planning a businessman is able to identify various alternatives and after proper evaluation, select the best alternative.

The term business and plan go together. In a business whether small or big a businessman has to plan continuously for one aspect or the other. He needs to know whether his business idea is a promising one or not and he requires a step by step investigation and development of sound business idea. Hence, the need arises for him to make a business plan.

8.2 MEANING OF BUSINESS PLAN

To start with, a businessman goes through the process of identifying various opportunities for the business. He studies the feasibility of various business proposals. He tries to determine the desirability of investing in a particular idea. He tries to establish the viability from different angles such as technical, marketing, financial, economic, managerial etc. If the resulting data show a non-viable project, the various parameters can be adjusted. A particular project can be abandoned if it proves to be not viable despite all alterations. Thereafter, feasibility of a new project should be analysed. If the idea is a promising one then a proper analysis should be done in respect of market, technical, and other aspects. In other words, make a business plan i.e. plan for the business.

A business plan involves step by step investigation and development of a sound business idea. A business plan can be said to be a comprehensive course of action with guidelines for a new venture. It covers the full range of business planning activities. It helps the entrepreneur to make better decisions. A business plan is also called feasibility plan. It is the systematic development of a project idea for the eventual purpose of arriving at an investment decision.

Who will write the Business Plan?

The businessman himself is responsible for planning as no other person will have the same motivation vision or foresight. He is, therefore the best person to draw up a business plan. In case, he is unable make the business plan himself he can take services of counselling organisations who deal in new venture planning. Various State Agencies like the Small Industries Service Institute (SISI), Small Industries Development Organisation (SIDO) etc. which are established to encourage venture development, also help the entrepreneur in this regard. For larger projects, a project team can be set up consisting of experts like industrial economists, market analysts, engineers, management accounting experts etc.

Example

Krishna Kumar has several business ideas in his mind. He can start manufacturing biscuits and cookies at a small level or make plastic refill bottles or simply become a wholesaler. After initial screening, he realises that last two ideas are not feasible and so abandons those ideas. He, then, starts making a business plan for the idea which he thinks is a promising one.

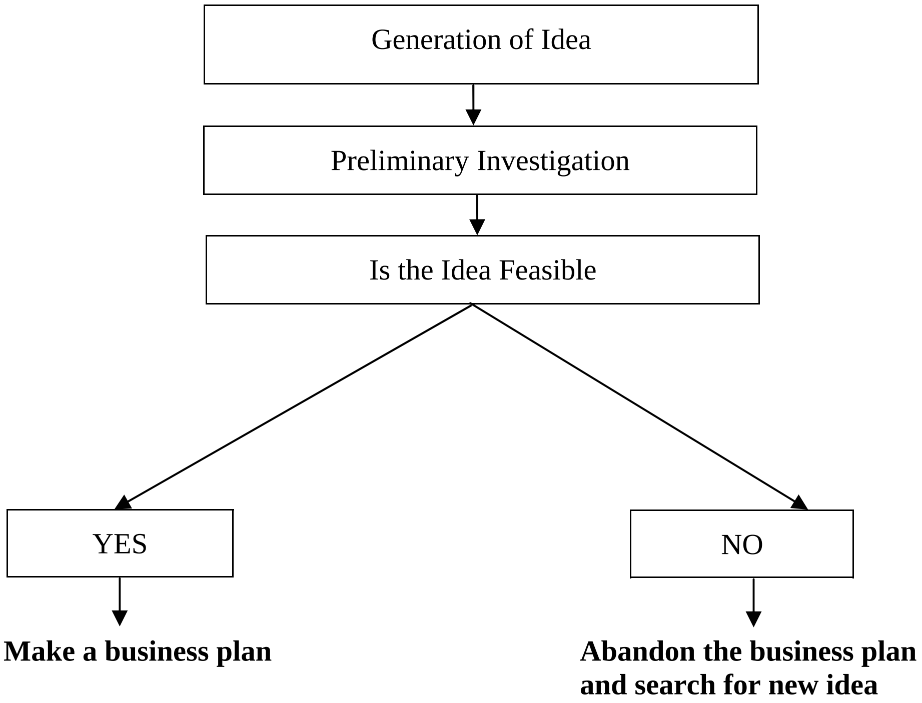

Figure 8.1: Diagrammatic representation of whether to make a business plan or abandon it and search for new idea

8.3 WHY A BUSINESS PLAN IS NEEDED?

A businessman needs a business plan because it serves the following purposes:

1. *Provides framework*

   A business plan provides a framework of future activities of the enterprise. Consequently, it will also shape the future pattern of services. It will provide an initial effort to show that a business idea can be realised and will provide reasons as to why it will succeed.

2. *Initiates development*

   A business plan will initiate the process of development. He can plan his production targets, employment, income generation and so on.

3. *Helps in arranging financial assistance*

   A business plan acts as the best means for obtaining the required assistance from financial institutions. A project report can be prepared on the basis of business plan and after proper analysis the businessman can get the required amount of money in the form of loans.

4. *Helps in selecting appropriate technology*

   A business plan helps the entrepreneur to examine his project idea thoroughly as regards its design, production, and technology to be used etc.

5. *Helps in securing clearances from the government*

   A business plan is also of great help in obtaining necessary clearances from the Government. A businessman can prove his credentials with the help of a well formulated business plan. The procedural formalities can be easily cleared. A business plan will pin point the matters for which Government sanctions have to be obtained.

6. *Provides knowledge about government regulations*

   A business plan helps a businessman in understanding various government directives, import and export policies etc. Scanning the ‘guidelines for industries’ published by the Ministry of Industry, a businessman can obtain information regarding industrial policy, licensing procedure, foreign collaboration, foreign exchange orders etc.

Features of an Ideal Business Plan

Following are the important features of an ideal business plan:

1. It should be written in simple language.
2. It should be informative.
3. It should clearly identify the products, services, markets and promoters of the business.
4. It should be complete and accurate.
5. It should be convincing so that the bankers are able to sanction loans.
6. It should be dynamic in nature.
7. It should have a pragmatic approach.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Fill in the blanks.

   i) A business plan is a broad set of ------------------------ for new venture.

   ii) A plan is to look ---------------.

   iii) An idea which is not feasible should be ---------------------.

   iv) A project report can be prepared on the basis of ---------------------.

   v) A business plan should have a --------------------- approach.

2. Name two organisations from where a businessman can avail services to make a business plan.

   i) …………………………………………………………………………...

   ii) …………………………………………………………………………...

3. State True or False

   i) A business plan should be static in nature.

   ……………………………………………………………….................

   ii) A business plan should be informative,

   ……………………………………………………………….................

iii) The entrepreneur should refer the 'guidelines for industries' before making a business plan.

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iv) A project team is required for small projects.

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v) A banker is the best person to write a business plan.

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8.4 INPUTS REQUIRED FOR A BUSINESS PLAN

A business plan, also known as feasibility plan, comprises several elements which should be taken into account. Following inputs go into the making of a business plan:

I. Information about the Industry
II. Information about the Enterprise
III. Information about Product/Service
IV. Information about Market Research
V. Information about Market Plan
VI. Information about Operation Plans
VII. Information about Finance

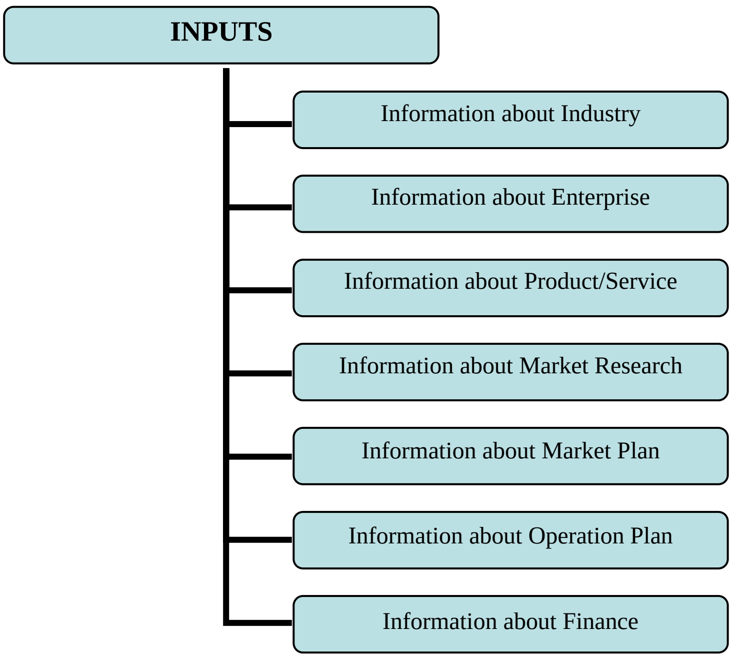

Figure 8.2: Diagrammatic representation of inputs that go into making of a business plan

Let's, now discuss these inputs one by one.

I. Information about the industry

A business plan, to start with, should contain an analysis of the industry. It should contain information like type of industry, its past and present performance, allocation of investment of funds, choice of technique etc.

II. Information about the enterprise

Information about the enterprise includes analysis of past performance, capacity utilisation, profitability etc. The purpose of the new venture (like manufacturing, processing, trading, providing services etc.) should be clearly defined. Forms of business organisation (like sole proprietorship, partnership, company, co-operative etc.) should also be mentioned.

A business plan should describe the entrepreneurial team as well. The skills, qualification, strength, talent etc. of the founding entrepreneur (also known as promoter) and other key personnel which are essential for the success of the firm must be described. The role of each person in the new venture should also be described briefly.

III. Information about product/service

Every business plan should explain its product to be sold or service to be offered. Usually, following points are described:

- Name of the product to be manufactured.
- The stage the business firm has reached to develop the new product e.g. whether such product is at research stage, design stage, testing stage, etc.
- The quality of the product.
- Price of the product.
- Method of using the product
- Material required.
- Cost of the product.
- Method of manufacture (e.g. technology profile).
- Legal protection (e.g. patents, trade mark, copy right etc.).
- Potential of substitute product which may pose competition.
- Licence requirement.
- Diversification plan.

IV. Information about market research

Under this head, the findings of market research should be provided so that it can be proved that a market really exists for the proposed venture. The entrepreneur must provide a summary of the following important points:

i) *Potential customers:* Information about potential customers helps in explaining the market size and likelihood of generating sales. Following factors are analysed under this head:

- Age of the customer
- Gender of the customer
- Family income
- Occupation
- Location

ii) *Market:* A business plan is a forecast for the present and future market. It includes information about market trend etc.

iii) *Competitors:* A business plan should provide information about the potential competitors. This includes:

- Identification of existing competitors.
- Explanation of their strengths and weaknesses.
- Impact of the new venture on the rivals.

iv) *Pricing system:* Under this head the following information should be analysed:

- Price of the product
- Credit Policies
- Discount system
- Pattern of Allowances

v) *Distribution system:* As regards distribution system, methods of distribution should be analysed. These methods include:

- Direct Sales through showrooms, mail etc.
- Distribution through retail houses.
- Distribution through wholesale establishments.
- Distribution through franchising system.
- Distribution through telemarketing.
- Distribution through door-to-door selling.

V. *Information about market plan*

A market plan can be made after proper market research. The purpose of this input is that the reader of the plan (i.e. businessman himself, investor, banker etc.) must be convinced that a viable market exists and the enterprise has a good opportunity to serve this market. It describes the intended strategy of a businessman. Following inputs should be provided:

- Product – quality, use etc. of the product.
- Pricing System – pricing method, discounts, allowances, taxes and duties, quantity, etc.
- Promotion – branding, advertising, demonstration, gifts, coupons, etc.
- Distribution – use of market channels or other approaches.
- Services – after sales service policies, installation and repair services, guarantee and warranty of a product, etc.
- Names and designations of the persons responsible for marketing and sales.

VI. *Information about operation plans*

Under this head the following important aspects shall be covered:

- Choosing a location
- Purchasing property
- Parking and transportation services
- Dealing with legal issues
- Renovations
- Equipment and technologies
- Inventory management
- Human resources
- Quality control

- Insurance
- Patents
- Copy-rights

VII. Information about finance

Money is one of the important measures used to gauge the progress of a firm. Hence, a business plan should include projections of financial statements which are based on operating and marketing assumptions.

A projected profit & loss account is required to show net profit. A projected balance sheet will reveal the financial position by showing the balances in various assets and liabilities accounts. A break-even analysis will reveal when the enterprise shall begin to earn a profit. A projected cash flow statement will show the movements of cash in and out of the firm and its net impact on the cash balance with the firm.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Mention any two points regarding enterprise which should be stated in the business plan.

   i) ……………………………………………………………………………...

   ii) ……………………………………………………………………………...

2. Who can be a part of entrepreneurial team?

   i) ……………………………………………………………………………...

   ii) ……………………………………………………………………………...

3. Match the following:

Column I	Column II
1) Market plan	A) Projected income statement
2) Operation plan	B) Potential customers
3) Financial plan	C) Use of market channel
4) Production	D) Renovation
5) Market research plan	E) Patents

8.5 PREPARATION OF PROJECT REPORT

Meaning of Project Report

A project report is a formal version of a business plan. It gives a complete analysis of inputs and outputs of the project. It enables the entrepreneur to understand at the initial stage whether the project is sound on technical, commercial, financial and economic parameters. On the basis of project reports an entrepreneur takes his decision on whether to proceed on the proposed project or not. The financial institution will also base their decision to extend finance and other support on the basis of the project report. A project report also helps in convincing the investors operating in the money market to invest funds in the business.

It is necessary to prepare a project report according to the format of the loan application of the concerned term lending institutions. The project report can be made either by the entrepreneur himself or by a consultant.

Aspects covered under a Project Report

A project report provides a bird's eye view of all the activities of a business firm. The various aspects of the information have to be systematically estimated and presented mentioning the various opportunities and constraints.

A project report includes information on the following aspects:

i) Economic aspect
ii) Ecological aspect
iii) Marketing aspect
iv) Technical aspect
v) Financial aspect
vi) Managerial aspect

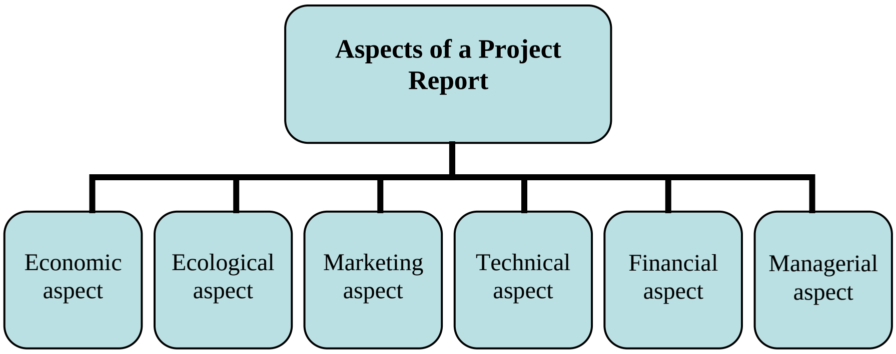

Figure 8.3: Diagrammatic representation of various aspects of a project report

Let's now discuss these points one by one:

i) Economic aspect

It is also referred to as social cost benefit analysis. It is concerned with judging a project from the larger social point of view. Under this, social costs and benefits are analysed. The impact of the project on the distribution of income, level of savings and investments in the society are analysed. It is to be seen that how much employment, self-sufficiency etc. the project will generate.

ii) Ecological aspect

Environmental concerns have assumed a great deal of importance in the present scenario. Ecological analysis is to be done for major projects which have ecological implications like power plants and irrigation schemes and environmental polluting industries. The likely damage caused by the project to the environment is to be seen.

iii) Marketing aspect

The project report should indicate demand for the product and the market share the project under appraisal can obtain. Information regarding consumption trends, structure of competition, elasticity of demand, distribution system, marketing policies, legal constraints, cost, preferences and requirements of consumers, etc. should also be mentioned. In other words a detailed market plan, specification of a proper marketing strategy and the manner in which the marketing process would be undertaken should be stated.

iv) *Technical aspect*

The appropriate report should give details about the techniques and technologies needed, equipments, raw material, machinery, power and other inputs required and the sources of their availability. This aspect covers the optimal scale of operation. Information regarding location and site, size, plant capacity, etc. needs to be mentioned.

v) *Financial aspect*

The report should indicate the amount of capital required. The amount to be contributed by the proprietor should be mentioned and the various other sources of finance should be indicated. Expected rate of return should be specified. Cost of project, projected profitability, break-even point, cost of capital, level of risk, projected financial position should be clearly indicated.

vi) *Managerial aspect*

The report should contain qualification and experience of the entrepreneurs and key personnel i.e. the persons who will be managing the show.

Contents of the Project Report

Following are the various particulars in brief to be given in a project report:

i) General details about the industrial concern, project and financial assistance applied for.

ii) Bio-data of promoters with past history.

iii) Particulars of the industrial concern comprising:

- A brief history.
- Proprietor's/partners' bio-data.
- Full details of revaluation of assets together with the reasons therefor.
- Bio-data of key technical and executive staff.
- Existing long term and short term borrowings.
- Particulars of production and sales.
- Locational advantages.
- Existing requirement of various utilities and services.
- Details of exports and incentives.
- Details of Insurance.

iv) Particulars of the project comprising:

- *Capacity* – Present and proposed installed capacity, maximum production achieved and planned

- *Process* – Details of technical process, labour intensiveness of the process, reasons for choosing a particular process.
- Technical arrangement – Details of the technical arrangement made or proposed, write up on the collaborator, copy of the Government approval for the collaboration etc.
- Management.
- Location of land
- Building
- Plant and machinery
- Raw material
- *Utilities* – Details about power, water etc.
- *Effluents* – Details of the nature of atmosphere, soil and water pollution likely to be created by the project and measures proposed for control of pollution.
- Labour.

ii) Cost of the Project.

iii) Means of Financing.

iv) Marketing and selling arrangement.

v) Government consents.

vi) Requirement of raw material.

vii) Particulars of machinery to be imported.

viii) Margin money for working capital.

ix) Source of funds in respect of expenditure already incurred.

x) Cash Flow Statement.

xi) Projected Balance Sheet.

xii) Projected Income Statement.

xiii) Calculation of wages and salaries at maximum production.

xiv) Unit cost of production.

xv) Declaration that the above particulars are true and correct to the best knowledge and belief of.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State True or False.

   i) A project report is an incomplete analysis of inputs and outputs of the project.

   …………………………………………………………………………...

   ii) A project report serves as a guide to management.

   …………………………………………………………………………...

iii) A project report can be prepared by anybody.

…………………………………………………………………………...

iv) A project report contains economic and financial aspects only.

…………………………………………………………………………...

v) A project report is needed by an entrepreneur for carrying out expansion or starting a new production line.

…………………………………………………………………………...

2. Read the following paragraph and fill in the blanks with appropriate words given below:

(entrepreneur, financial institutions, analyse, expert, feasibility)

A project report is prepared to ------------------- the extent of opportunity in the contemplated project. It is prepared by the-------------------------- himself or an ------------------- after detailed study and analysis of the various aspects of a project. The ------------------- insist upon such a project report in order to be sure about the ---------------- of the project.

8.6 PROJECT APPRAISAL

In the preceding paragraph we learnt that the entrepreneur has to submit a project report to his bankers in order to avail loan facility from them. The bank/term-lending institutions after receiving the loan application along with project report critically scrutinise it. They intend to ascertain the possibility of generation of funds by the project itself and whether or not it would be substantial enough to repay the amount advanced within the fixed time. The following paragraphs focus on what goes on in the minds of financial institutions while they appraise the proposal.

Let's now discuss the system of project appraisal.

Meaning of Project Appraisal

Project appraisal is the assessment of a project by a bank/term-lending institution. It is a complete and critical scanning of the project. It is the analysis of cost and benefit of the proposed project. It is important for a bank/term-lending institution to appraise a project because the resources are always limited and choice among alternative projects has to be made.

Method of Project Appraisal

The method of analysis of a project report usually varies from project to project i.e. method of analyzing a project by Canara Bank may be different with that of Delhi Financial Corporation. The various aspects that are taken into account by the appraiser are examined below:

i) Economic viability

The larger projects may be critically evaluated by the lending institutions by taking into those factors which have an economic and socio-cultural impact on the society. The appraiser will examine whether the project will lead to increased output, increased employment, larger Government revenues, higher standards of living, increased national income, utilisation of indigenous raw-material, etc.

ii) Ecological viability

Effect of the project on the environment with particular emphasis on the pollution of water and air caused by the project is examined. The arrangement for effective disposal of effluents as per the Government policies is also judged. Energy conservation devices etc. employed for the project are also analysed. This analysis is done for big projects.

iii) Technical viability

All factors relating to infrastructural needs, technology, availability of machines, materials etc. are required to be scrutinised. Following are some of the important points which are usually examined under this head:

a) Size of the available land to meet the present requirements and future expansion plans.

b) Locational advantages in terms of transport facilities, proximity to market, infrastructural facilities like availability of water, power, labour etc.

c) Position of availability of licences, if required from the Central or State Governments.

d) Technology selected and method of manufacture.

e) Technology collaboration, if any.

f) Ready availability of plant and machinery.

g) Arrangements for servicing of the machinery, supply of spare parts etc.

h) Scale of operation.

i) Plant layout and plant capacity.

j) Detailed specification and the quantity proposed to be manufactured for, say, five years.

k) Specifications for raw material and sources of supply.

iv) Marketing viability

Any project can be commercially viable only if it is able to sell its products at a profit. For this purpose, demand and supply pattern of that product is examined. Various methods like trend method, regression method for estimation of demand are employed which are then matched with the availability of particular product. Some of the important aspects which are analysed under this heading are given below:

a) Study of demand forecast.

b) Market potential.

c) Position of other competitors.
d) Distribution channels.
e) After sale-service.
f) Capability of the organisation to survive even under the adverse circumstances.

v) Managerial viability

The background of the founders or promoters of the project is also closely examined by the lending institutions. The project report should also highlight the strengths and weaknesses of the management by commenting on qualification, experience, potential, etc. of the key personnel. Following points are usually critically observed:

a) Organisation Chart clearly defining various ranks and their jobs.
b) Functions assigned to various managers.
c) Communication channels.
d) Delegation of authority and responsibility.
e) Labour relations.
f) Workers' participation in management.
g) Turnover rate.
h) Social security.
i) Working conditions.
j) Fringe benefits.
k) Qualification and experience of the founders/promoters.
l) Training programmes.
m) Internal control systems.

In short, the appraiser wants to be sure that the project is adequately carried out through a well-staffed organisation which is capable of contributing effectively to the success of the project and organisation thereby. The qualification and past experience of the founders is assessed to know their capabilities for implementing the project.

vi) Financial viability

The real objective of the appraisal of the financial aspect of a project report is usually to examine its financial condition for the sound implementation of the project. The financial institution wants to ensure that the business firm is in a position to manage its business in a cost-effective manner as well. Financial viability of the project is also seen to assess whether a project would be in a position to generate enough surplus for timely payment of interest and servicing of debt in a reasonable period of time. The financial aspect of project appraisal covers the following areas:

A) Cost of project

- Cost of land and building
- Cost of plant & machinery
- Furniture and fixtures
- Office equipments
- Interest during construction period

- Margin money for working capital
- Preliminary expenses

B) *Sources of finance*

- Owned Capital
- Unsecured Loans from friends and relatives
- Term Loans from financial institutions/commercial banks
- Deferred Term Credit
- Subsidies and Development Loans

C) *Projected income statement*

Trading account provides net sales figures and details of direct expenses relating to raw material, wages, power, fuel etc.

Profit & loss account provides figures of net profit after taking into account expenses like salary, office expenses, selling and distribution expenses, interest, depreciation etc.

D) *Projected balance sheet*

The lending institution will study the projected balance sheet as well which gives the position of assets and liabilities of the business unit at a particular time. It shows the assets and liabilities of a firm.

E) *Break-even analysis*

A break-even point of a business enterprise is the level of output or sales at which the business enterprise just breaks-even i.e. there is neither a profit nor a loss. The formula for calculating break-even point (BEP) is as under:

$$\textbf{\textit{BEP (in Units)}} = \frac{\text{Total Fixed Costs}}{\text{Selling Price per unit} - \text{Variable Cost per unit}}$$

A unit should always work above the break-even point to earn profit.

F) *Financial ratios*

While analysing the financial aspect of a project, study of financial ratios is quite important. These ratios can apprise the financial institutions about the liquidity position, solvency position of a firm over a period of time. The financial ratios which are usually analysed are:

- Debt-Equity Ratio
- Debt-Service Ratio
- Current Ratio
- Liquid Ratio
- Stock Turnover Ratio
- Debtors' Turnover Ratio
- Return on Investments
- Working Capital Turnover Ratio

G) *Projected cash flow statement*

A projected cash flow statement is a summary of all the sources of cash available (cash inflows) during the course of operation within a period of time and its possible uses (cash outflows) during that period. While appraising the project the banker, with the help of this statement, can find out the total surplus funds created during the operational year for which it is prepared. This information helps to determine the capacity of the project to service its debts and fix the repayment period and moratorium period of loan.

H) *Pay back period*

While carrying out project appraisal the banker considers a project more favourably which has shorter pay back period. This period refers to the length of time which is required to recover the initial cash investment made in a project. A project with a shorter pay back period is always preferred.

I) *Discounted cash flows*

Under pay back period the cash flows are considered without taking into account the time value of money. It may be noted that the value of a particular amount received after five years is not similar to the value of same amount which is received today.

For example, there is a difference between Rs. 10,000 which is received after five years and which is received today. If we compute the present value of Rs. 10,000 which shall be received five years hence, it must be discounted at a particular rate of interest to know its present value.

The banker shall consider the present values of the future cash flows and compare it with the initial investment. If the result is positive i.e. the present values are more the project shall be acceptable.

J) *Internal rate of return*

At the time of appraisal the bankers also consider the internal rate of return (IRR), also known as accounting rate of return. IRR means the discount rate which equals the present value of investment in the project to the present value of future returns earned during the life time of the project. IRR indicates earning capacity and a higher IRR indicates better prospects for the project.

8.7 COMMON ERRORS IN FORMULATION OF BUSINESS PLAN AND REMEDIES THEREOF

Common Errors in Business Plan Formulation and Remedies

Following Table indicates the various common errors which may be committed while formulating a business plan. The Table also contains remedies which will help in avoiding such errors:

Table

Common errors	Remedies
i) The entrepreneur may make heavy investment in land and building in the initial stages which may result in un-economic working due to heavy interest burden on un-productive assets if these are under-utilised.	At the initial stages heavy investment in un-productive assets should be avoided. Such investment may be diverted for purchasing imported machinery and good quality raw material.
ii) Plant and machinery purchased is unbalanced i.e. the capacity at various stages of production is not matched to give the desired output which may result in low production.	A critical analysis of the various technical factors can help the entrepreneur to prevent the unit from getting into difficulties at a later stage.
iii) The management is ineffective in controlling functions like production, marketing, finance etc.	Experienced personnel should be recruited. Their roles should be clearly defined with proper delegation of authority.
iv) The business is more at risk if decision making in all areas is in the hands of one man i.e. one man show.	The businessman should keep important decisions in his hands. Routine business activities should be delegated. Principle of '*management by exception*' should be followed.
v) Promoters are weak in respect to experience, qualification etc.	Experts may be roped in either as partners or employees or consultants.
vi) The project report may not show enough profits to service its debts and for future development.	Avoidable and unnecessary expenditure may be reduced.
vii) A project report when written by the businessman himself may contain mistakes.	The project report may be prepared with the help of experts.
viii) Projections given in the project report are only for short period.	The project report should contain projections for at least five years.
ix) Wrong and unrealistic estimations are incorporated in the project report.	Wrong and unrealistic estimations should be avoided. The estimations should be based on authentic information.
x) Insignificant ratios like Fixed Assets Turnover Ratio, Fixed	Significant ratios like Current ratio, Debtors' turnover ratio, Debt service

asset ratio etc are given in the project report.	coverage ratio, Debt equity ratio etc. should be invariably incorporated.
xi) Wrong estimate of fixed capital are incorporated in the business plan leading to long term adverse effects on the financial position of the enterprise and also on its profitability. It may lead to over/ under capitalisation.	With careful planning the businessman should correctly estimate the fixed capital so that there is no under or over capitalisation in the long run.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Tick the correct option from the following alternatives:

   i) A project report is appraised by:

      a) Banker
      b) Businessman
      c) Central Government
      d) Reserve Bank of India

   ii) The financial projections appraised are:

      a) Projected income statement
      b) Projected financial position
      c) Both of the above
      d) None of the above

   iii) The purpose of project report appraisal is to:

      a) Recruit financial manager
      b) Buy land and building
      c) Sanction term loan
      d) None of the above

   iv) The banker will examine:

      a) Technical viability
      b) Economic and Financial viability
      c) Marketing viability
      d) All of the above

   v) The point which may go against the promoter:

      a) Good Qualification
      b) Wide Experience
      c) Works on whims and fancies
      d) Sharp business acumen

2. Mention any two points which will be examined by the bank at the time of project appraisal.

   ………………………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

3. Mention any two common errors which a project report may contain.

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

8.8 LET US SUM UP

Business plan is prepared to assess the future and make provisions for it. A businessman studies the feasibility of various business proposals. He takes up only that idea which is promising one. With this idea in hand, a proper analysis should be done in respect of market, technical, and other aspects. At this stage, the business plan which involves step by step investigation and development of a sound business idea should be prepared. Besides businessman himself, the business plan can be written with the help of experts also. A business plan is required because it provides a framework for the future activities of the enterprise. It helps in initiating development, arranging financial assistance, securing clearances from the Government, selecting appropriate technology etc. The important inputs that go into making of business plan include information about the industry, enterprise, product and service, marker research, market plan, operation plans, and finance. A project report is a formal version of a business plan. A project report includes information about the various aspects like economic aspect, ecological aspect, marketing aspect, technical aspect, financial aspect and managerial aspect. Financial institutions including banks appraise a project report for its viability etc., if any financial assistance is desired by the businessman from such institutions. Common errors like over estimations, heavy investment in unproductive assets, wrong projections etc. should be avoided while formulating business plan.

8.9 KEY WORDS

Cost of capital : It is the rate of return required by the investors on capital provided by them.

Cost of project : It is the total of all items of outlay associated with the project which are supported by long term funds.

Plant capacity : Volume/number of units that can be manufactured during a given period.

8.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. i) Guidelines
   ii) Ahead
   iii) Abandon
   iv) Business Plan
   v) Pragmatic

2. a) Counselling Organisations
   b) State Agencies

3. i) False
   ii) True
   iii) True
   iv) False
   v) False

Check Your Progress Exercise 2

1. **Hint:** i) From the business organisation
   ii) Analysis of past performance.

2. **Hint:** i) Promoters
   ii) Experts in the field of finance, Production etc.

3.

Column I	Column II
1) Market Plan	C) Use of market channel
2) Operation Plan	D) Renovation
3) Financial Plan	A) Projected Income Statement
4) Production	E) Patents
5) Market Research Plan	B) Potential Customers

Check Your Progress Exercise 3

1. i) False
   ii) True
   iii) False
   iv) False
   v) True

2. *(analyse, entrepreneur, expert, financial institutions, feasibility)*

Check Your Progress Exercise 4

1. i) a) Banker
   ii) c) Both of the above
   iii) c) Sanction term loan
   iv) d) All of the above
   v) c) Works on whims and fancies

2. **Hint:** i) Financial viability of the project.
   ii) Managerial viability of the project.

3. **Hint:** i) The entrepreneur may make heavy investment in unproductive assets (like land and building) in the initial stages.
   ii) The project report may not show enough profits to service its debts and for future development.

8.11 SOME USEFUL BOOKS

1. Desai, Vasant (1998) Dynamics of Entrepreneurial Development of Management; Himalaya Publishing House, Mumbai, Reprint.

2. Nabhi Publication (2004) How to Borrow from a Baking and Financial Institution; Nabhi Publications, New Delhi, Edition.

3. Bidani, Mitra and Promod Kumar (1998)Bank Finance for Industry; Vision Books, New Delhi, Edition.

4. Chandra, Prasanna (1996) Projects, Planning, Analysis, Selection, Implementation and Review; Tata McGraw-Hill Publishing Company Limited, New Delhi, Fifth Reprint.

8.12 ASSIGNMENTS

1. What is a business plan? Why is it needed?

2. What are the features of an ideal business plan?

3. Explain in detail the various inputs required to be mentioned in a business plan.

4. What is a project report? Why is it prepared?

5. “A business plan comprises several elements”. Name any two.

6. Mention two points relating to product which should find place in a business plan.

7. What is a market plan?

8. What is the purpose of a projected cash flow statement?

9. Explain the various aspects to be covered in a project report.

10. What is the purpose of social cost-benefit analysis?

11. Mention the contents of a project report.

12. What is project appraisal? Who does it?

13. Discuss how the banker will examine technical and financial viability of the project.

14. Mention the various sources of finance which the banker may examine.

UNIT 9 ARRANGING THE INPUTS: FINANCE AND MATERIAL

Structure

9.0 OBJECTIVES

After studying this unit, you should be able to:

- know the meaning and importance of finance;
- understand the various types of capital;
- identify the different sources of finance;
- comprehend the factors involved in selection of appropriate medium of finance; and
- understand the important considerations associated with procurement of material.

9.1 INTRODUCTION

A businessman has innumerable tasks the moment he decides to venture into the line of business. Some tasks out of these may be highly important and crucial for his business to start and gain momentum; while some other tasks may not be so important. The most important task for a businessman is no doubt, to decide 'about what to do'? Should he go into manufacturing line and become a producer or should he divert into a wholesale or retail trade business. Once this important decision is taken then follows the other significant tasks of organizing various resources for his business.

To start with, a businessman needs to assemble five M's i.e. money, material, men, methods and machines for his business. These are the basic inputs required for his business – more so if he plans to be in manufacturing line. In this Unit an attempt has been made to highlight the importance and management of the first two inputs i.e. **money, also known as finance; and material.**

Finance is an important input as no business can function without money and material is important because goods cannot be manufactured without raw material.

9.2 FINANCE: MEANING, NEED AND TYPES

"Finance is the life-blood of any business" – is rightly observed. Finance is required by all types of business – big or small, manufacturing or trading, etc. Finance acts as the lubricant for the wheels of the business to move and to run. No business firm can carry out its work without money. Money is one of the five M's of business – the other four being men, material, machinery and methods. Provision of finance leads to economic development of the country. Past two decades have shown an increase in setting up of SSIs due to availability of finance on easy and better terms. The amount of finance required may be different from one business to another. It depends upon many factors like nature of the business, size of the business, time-period, etc.

A businessman needs money for the following purposes:

i) To start a business;
ii) To expand, renovate and modernize the business.

Types of Capital

Following are two the types of capital required by a businessman:

1. *Fixed capital*

   Fixed capital is required to acquire fixed assets like land, building, plant, machinery, office equipment, furniture and fixtures, erection and installation of machinery, etc. In addition, fixed capital is also required for meeting the cost incurred on insurance, technical know-how etc.

2. *Working capital*

   Working capital is needed to meet day-to-day requirements of a business. For example, amount spent on raw material, wages, hire charges, transportation, interest, etc. It is also known as circulatory capital. Once the raw material is purchased and products are manufactured, the process of selling the goods so manufactured starts. Thereafter, efforts are put in to realise the sale proceeds including that amount of money which gets locked due to the credit sales. The money so realised is once again invested in purchasing raw material and the operating cycle is continued. Hence, the term circulatory capital.

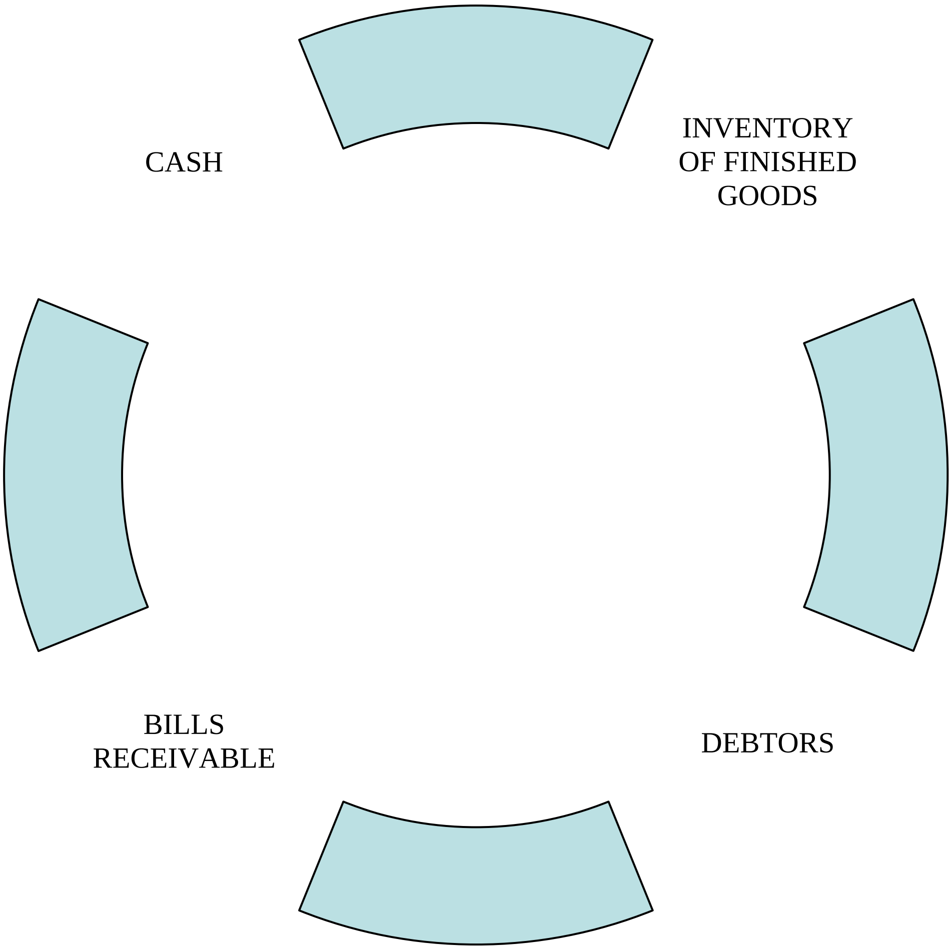

Figure 9.1: Diagrammatic representation of operating cycle in a trading firm selling goods on credit

Types of Finance

For financing fixed capital and working capital a businessman needs long term finance as well as short term finance**.**

1. *Long term finance*

   Long term finance is used for investment in fixed assets such as land and building, plant and machinery etc. It is used to meet the permanent needs of business. It can be raised through owned capital and long term loans. Such finance cannot be withdrawn from the business.

2. *Short term finance*

   Short term finance is used for investment in working capital. It is used to meet the short term needs of the business. For example, purchase of raw material, payment of wages etc. These funds are normally required for a period ranging from three months to two years.

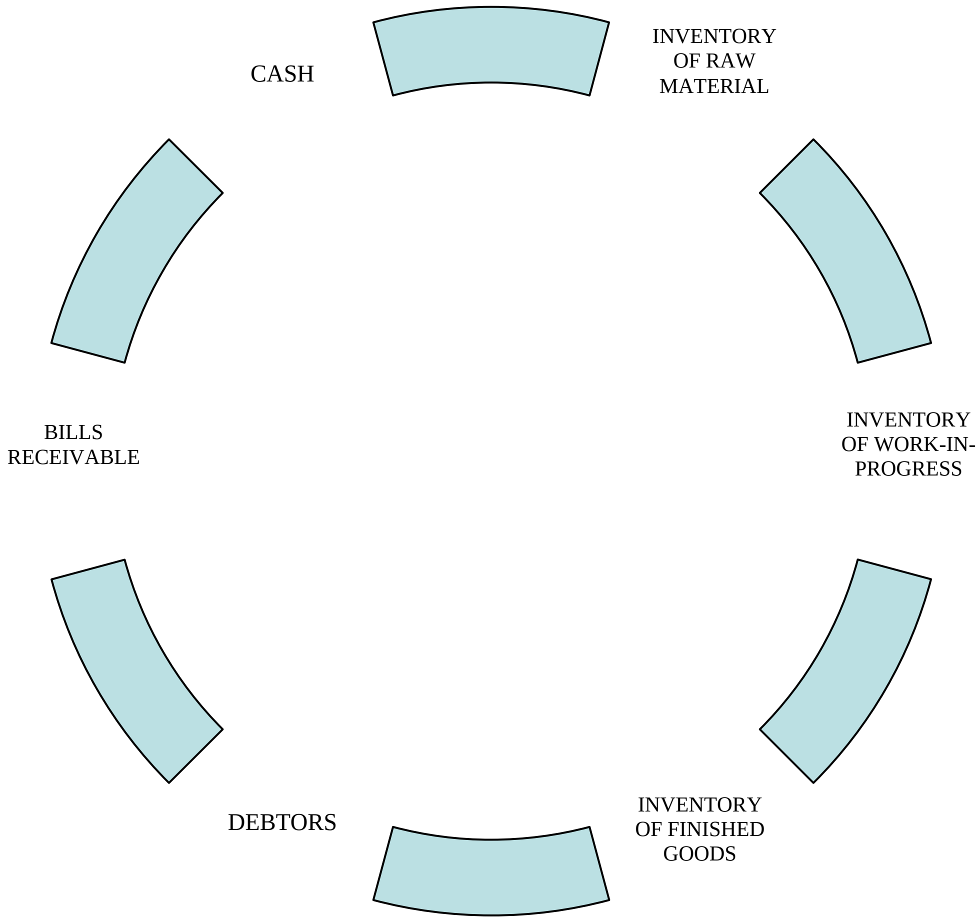

Figure 9.2: Diagrammatic representation of operating cycle in a manufacturing firm selling goods on credit

9.3 SOURCES OF FINANCE

The sources of funds can be broadly divided into:

i) owned capital; and
ii) borrowed capital.

Owned capital is the money brought in by the businessman himself, while borrowed capital is the money advanced by outside agencies. However, sources can also be segregated into long term sources and short term sources. These sources are explained below:

Sources for Long Term Finance

1. Owned capital
2. Retained Profits
3. Funds borrowed from friends and relatives.
4. Loans from Commercial banks
5. Loans from National-level Financial Institutions
6. Loans from various State-level Financial Institutions

Let's now discuss the above sources of finance.

1. *Owned funds*

   Owned funds are the funds provided by the owners. In case of a sole proprietor, the individual himself provides the owned funds from his personal property and past savings. In a partnership firm, the funds contributed by partners as capital are called owned funds. In a joint stock company funds, raised through issue of shares, are known as owned funds.

2. *Retained profits*

The businessman may not withdraw the entire profit from the business. Retained profit represents the amount of profit which remains available in the business after taking out profit for his personal and family affairs. Retained profit serves as a long term source of finance.

3. *Friends and relatives*

Amount can also be collected from the friends and relatives of the businessman. They generally provide this form of assistance at either no or very low rate of interest. The repayment schedule may not be fixed and generally no amount is kept as security. This is provided only due to love and affection.

4. *Loans from commercial banks*

A lot of importance has been put on the role of commercial banks by the successive governments in the development of the economy of our country. It is quite evident that various commercial banks are, therefore, associated with every project of industry/trade irrespective of its size. The banks are catering to the credit needs of a large variety of projects, big or small, in all sectors of the economy including agriculture, trade, industry, services etc. Commercial banks grant term loans for small projects falling under priority sector, small scale sector and also to big units. Long term loans are usually repayable after a period of seven years.

Banks are playing an important role for the upliftment of rural and urban poor. In this direction, they are involved in implementing the various Government sponsored schemes like Swarna Jayanti Gram Swarojgar Yojana (SGSY); Prime Minister’s Rojgar Yojana (PMRY); Swarna Jayanti Shahari Rojgar Yojana (SJSRY); Scheme for Liberation and Rehabilitation of Scavengers (SLRS), etc.

5. *Loans from national-level financial institutions*

Various financial institutions play a significant part in development of big industries. Financial Institutions like Industrial Development Bank of India (IDBI), Small Industries Development Bank of India (SIDBI), Industrial Finance Corporation of India (IFCI), Industrial Investment Bank of India (IIBI), Industrial Credit and Investment Corporation of India (ICICI), Regional Rural Banks (RRBs), National Bank for Agriculture and Rural Development (NABARD) etc. offer financial assistance on long term basis for big projects. These are also known as development financial institutions. They are a major source of finance for forming of new business organisations and expansion of existing concerns. They also provide promotional, technical and managerial services to various new and existing organisations. The rate and repayment procedures are convenient and economical. Loans and guarantees in foreign currency and deferred payment facilities are available for the import of machinery and equipment.

6. *Loans from state-level financial institutions*

   State-level financial institutions were established because the National-level financial institutions were providing finance exclusively to large scale industrial units. The Government, therefore, started establishing development banks at the regional level to provide assistance to small scale industries. These institutions provide long term loans to industries for the purchase of land, building and machinery. They also assist in industrial activities like preparation of feasibility report, identifying entrepreneurs, assisting them in project implementation, etc.

Short Term Sources of Finance

Short term finance is required for meeting the short term requirements of business (like working capital). Short term loans are usually repayable within a period of one to three years. The important sources of short term finance are as under:

1. Bank Overdraft
2. Cash Credit
3. Discounting of Bills of Exchange
4. Short term loans
5. Trade Credit from suppliers
6. Accounts Payable
7. Advances from customers
8. Accruals
9. Factoring
10. Co-operative Credit Societies
11. Indigenous Bankers

1. *Bank overdraft*

   This is one of the most convenient methods of borrowing. Here, a customer having a current account with a commercial bank like Canara Bank is permitted to withdraw more than what he has deposited. The upper limit of what he can overdraw is fixed. Interest is charged on the amount actually overdrawn during a particular period. Some asset is kept as security. Overdraft limits are usually rolled-over limits which are renewed every year.

2. *Cash credit*

   A major part of working capital requirement of any industrial project generally consists of maintenance of inventory of raw material, semi-finished and finished goods, stores and spares etc. Even in trading concerns funds are required to maintain stock-in-trade. Finance against such inventory is granted in the shape of cash credit facility where cash withdrawals are permitted against stock of goods. A running account facility is provided where deposits and withdrawals are permitted to the borrower as frequently as required. Over-drawls are however restricted to an agreed limit and are further subject to availability of drawing power in the account.

3. *Discounting of bills of exchange*

   Commercial banks also extend financial assistance by discounting bills of exchange. Here the customer i.e. the businessman can get the amount of a bill receivable from the bank before the date of maturity. Charges have to be paid by the customer known as discounting charges.

4. *Short term loans*

Loans provided by commercial banks are repayable in monthly/quarterly/half-yearly/yearly instalments. Commercial banks grant short term loans and medium term loans for working capital requirements. Short term loans are repayable in less than three years while medium term loans are repayable in a period ranging from three years to seven years. A loan is granted against security of assets and the personal guarantee of the borrower. Collateral security is also demanded as and when necessary. Interest on loans is required to be paid on regular basis irrespective of the loss suffered by the borrower.

5. *Trade credit from suppliers*

Trade credit is the credit extended by the seller of goods to the buyer as incidental to sale. It is available in the ordinary course of business without any security. An open account credit arrangement is made, the volume of which depends upon the reputation of the buyer, financial position of the seller, volume of purchase etc.

6. *Accounts payable*

Accounts payable is another form of trade credit. Here, the buyer is required to sign a debt instrument e.g. a bill of exchange or a promissory note as an evidence of the amount due by him to the seller. This credit is also made available without creating any charge on assets.

7. *Accrual accounts*

There is usually a time-lag between receipt of income and making payment for the expenditure incurred in earning that income. During this time-lag the outstanding expenditure helps an enterprise in meeting some of its working capital requirement. For example, wages and salaries, taxes due but not paid immediately etc. Wages and salaries are paid in the first week of the month next to the month in which services were rendered.

8. *Advances from customers*

If the businessman is manufacturing a product which is in short supply, he may demand advance money from his customers at the time of accepting their orders. This is a very cheap source of short term finance because either no interest is payable or the rate of interest payable on advance is nominal.

9. *Factoring*

The businessman can obtain short-term finance through factoring. It is an arrangement under which the businessman assigns his book debts to the factoring firm. Against such assignment of debtors' balances the banker advances the money to the businessman. For providing the services of factoring, the factoring firm charges commission known as 'commercial charge'. SBI has opened a subsidiary by the name SBI Factors and Commercial Services Ltd. which provides factoring services. Similarly, Canara Bank has also opened a subsidiary by the name Canara Bank

Factors Ltd. for the purpose of providing factoring services in India. SIDBI has also introduced its own factoring services.

10. Co-operative credit societies

Co-operative Credit Societies are formed by artisans, agriculturists, industrial workers etc. These societies provide financial assistance at reasonably low rate of interest to its members. They also promote the habit of saving and thrift among them.

11. Indigenous bankers

Businessmen can get loans from various indigenous bankers as well. They are known by different names like shroffs, seths, sahukars, mahajans, etc. in different parts of the country. They vary in size from petty money-lenders to substantial shroffs who carry on large and specialized business. They finance the businessmen by means of hundies or bills of exchange. They lend against personal credit of the borrowers. The rate of interest is usually very high. They may not give receipts in most of the cases.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the source of finance in the following cases:

   i) Rakesh received Rs. 1,00,000 from his grand parents to start his business.

   ……………………………………………………………………………...

   ii) Shri Ganesh, a neighbour of Mukesh agrees to give Rs. 5,000 to him without any interest.

   ……………………………………………………………………………...

   iii) Suhail Khanna borrows Rs. 25,000 @ 5% p.a. from his brother-in-law.

   ……………………………………………………………………………...

   iv) M/s. Utkarsh & Sons took loan of Rs. 1,00,000 from Canara Bank repayable in three years.

   ……………………………………………………………………………...

   v) Kishore starts his business investing Rs. 50,000 in cash.

   ……………………………………………………………………………...

2. Classify the following expenses into fixed capital and working capital:

   i) Purchase of raw material.

   ……………………………………………………………………………...

ii) Purchase of plant & machinery.

……………………………………………………………………….....

iii) Purchase of land and building.

……………………………………………………………………….....

iv) Rent paid.

……………………………………………………………………….....

v) Purchase of 'Maruti 800'.

……………………………………………………………………….....

3. Name the sources of finance in the following cases:

i) A source of finance where credit is extended by the seller of the goods.

……………………………………………………………………….....

ii) A source of finance where expenses are paid in the first week of the month next to the month in which services were rendered.

……………………………………………………………………….....

iii) A source of finance where 'sahukars' or 'mahajans' grant credit to the business.

……………………………………………………………………….....

iv) A source of finance provided by commercial banks where a customer can withdraw more money than he has deposited.

……………………………………………………………………….....

v) A source of finance where the business can get the amount of a bill receivable from the bank before the date of maturity.

……………………………………………………………………….....

9.4 SPECIALISED FINANCIAL INSTITUTIONS

Specialised financial institutions mainly provide long term financial assistance in various forms. Besides sanctioning loans, the give guarantees for loan raised by the business concerns from other sources.

These institutions are also known as development banks because they provide not only capital but also knowledge and entrepreneurship to the industry. These institutions undertake potential industrial surveys; identify growth projects; provide technical, managerial and other assistance to the entrepreneurs.

These special financial institutions, both at National-level and State-level have been set up upon the initiative of the Central and State Governments respectively.

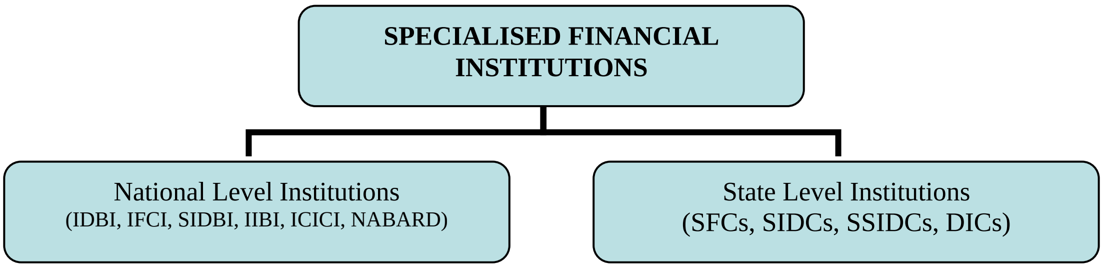

Figure 9.3: Diagrammatic representation of types of specialised financial institutions

Let's now discuss some of the important specialised financial institutions.

1. Industrial Development Bank of India (IDBI)

IDBI was set up as a wholly owned subsidiary of Reserve Bank of India in July, 1964 by an Act of Parliament. It serves as an apex level national institution for providing term finance to the industry. In 1976, the ownership of IDBI was transferred to the Government and it was entrusted with the additional responsibility of acting as principal financial institution for coordinating the activities of institutions engaged in the financing, promotion or development of industry.

Functions of IDBI

i) It provides direct financial assistance to industrial concerns by giving them long term loans.

ii) It provides technical and administrative assistance for promotion and expansion of industry.

iii) It guarantees loans raised by industrial concerns from other financial institutions.

iv) It accepts bills of exchange of industrial concerns and also discounts and rediscounts them.

v) It provides refinancing facilities.

2. Small Industries Development Bank of India (SIDBI)

SIDBI was set up by an Act of Parliament i.e. Small Industries Development Bank of India Act, 1989 as a wholly-owned subsidiary of IDBI for re-financing, bills rediscounting, and equity support to the small scale sector. It started functioning on April 2, 1990. SIDBI was de-linked from IDBI w.e.f. 27th March, 2000. It serves as an apex level national institution for promotion, finance and development of industries in the small sector.

Functions of SIDBI

i) It provides financial assistance through term loans and working capital.

ii) It provides finance through discounting and re-discounting of bills arising from the sale of machinery to small units.

iii) It provides Venture Capital support.

iv) It provides services like factoring, leasing etc.

3. National Bank for Agriculture and Rural Development (NABARD)

NABARD has been set up for the promotion of agriculture, small scale industries, cottage and village industries, handicrafts etc. in the rural sector. It is an apex bank for agricultural finance. It came into existence on July 12, 1982. It provides refinancing facilities. It has initiated Micro Finance programme under which millions of poor people have been provided access to credit. It has created special funds like Watershed Development Fund, Tribal Development Fund, Research and Development Fund, Farm Innovations Fund, and Micro Finance Development and Equity Fund to support innovations in neglected areas.

4. Regional Rural Banks (RRBs)

The object of setting up Regional Rural Banks was to bring the banking services to the doorsteps of rural masses. Initially these banks were providing funds to target groups comprising weaker sections of the society at a concessional rate of interest. However, since 1997 the RRBs have been allowed to lend outside the target group also by classifying their advances into priority sector and non-priority sector.

5. State Financial Corporations (SFCs)

A special law known as State Financial Corporation Act, 1951 was passed by the Parliament to enable all the states except Jammu and Kashmir to set up their own State Financial Corporations. So far 18 SFCs are operating in different States and Union Territories.

The main objective of SFCs is to finance and promote small and medium enterprises and projects costing up to Rs.5 crores for achieving balanced regional socio-economic growth and generating employment opportunities. SFCs operate a number of schemes of refinance and equity type of assistance formulated by IDBI, SIDBI which include schemes for artisans, SC/ST, women, ex- serviceman, physically handicapped etc. and for transport operators, for setting up hotels, hospitals etc.

SFCs can provide financial assistance to proprietary concerns and partnership firms up to Rs. 120 lacs.

Functions of State Financial Corporations

Following are the functions of SFCs:

i) They provide term loans for acquiring land, building, plant and machinery, other miscellaneous fixed assets etc.

ii) They establish polytechnics or training institutes for imparting training to technically qualified persons.

iii) They take up the development of lesser developed parts of the State and engage in infrastructure development like electricity, road, water etc.

iv) They promote self-employment.

v) They provide finance for expansion, modernization and up-gradation of technology in the existing units.

vi) They identify and examine local problems.

vii) They provide seed capital assistance under the schemes of IDBI.

viii) They provide deferred payment guarantees for purchasing plant and machinery.

ix) They provide foreign exchange loans to industrial units under World Bank Schemes.

General Terms and Conditions of Financial Assistance to Small Scale Units provided by SFCs

The general terms and conditions of financial assistance which may be provided to the small scale units are as follows:

1. *Quantum of assistance:* No minimum or maximum quantum of assistance has been stipulated except the upper ceilings.

2. *Debt-equity ratio:* SFCs may approve a Debt-Equity ratio of up to 2.5:1 for providing assistance.

3. *Promoters' contribution:* A minimum promoters' contribution ranging from 12.5% to 22.5% depending upon the location of project and category of enterprise may be accepted.

4. *Repayment period:* SFCs usually fix the repayment period after taking into consideration the profitability and debt servicing capacity of the project. No repayment period is fixed beyond 10 years.

5. *Rate of interest:* The rates are subject to revision from time to time.

6. *Commitment charges:* The commitment charges are payable only after the expiry of 12 months from the date of sanction. However, the rates may again vary from state to state. Usual Commitment Charges are as under:

For loans up to Rs.5 lacs:	*NIL*
For other Projects:	*1% p.a.*

Composite Loan Scheme of SFCs

Generally, SFCs provide assistance for term loan component and the unit has to arrange working capital requirements from a commercial bank of its own choice. SFCs, however, operate a composite loan scheme which meets all the requirements of the unit. Composite loans up to Rs. 50,000 are sanctioned under the Scheme to artisans, village and cottage industries and SSI units in tiny sector. The repayment period of such composite loans is spread from 3 years to 7 years.

Seed Capital Assistance provided by SFCs under the Scheme of IDBI

Under this Scheme maximum assistance per unit is restricted to Rs. 15 lacs. The following categories of entrepreneurs are generally eligible for assistance:

i) Entrepreneurs establishing small scale units for the first time.

ii) Entrepreneurs wishing to undertake expansion, diversification or modernization of small scale units and yet remaining small scale units.

iii) Entrepreneurs wishing to set up a medium scale unit for the first time or wishing to undertake expansion, diversification of existing industrial undertakings for better viability.

iv) Entrepreneurs taking over an existing sick or closed industrial unit.

Application under the Scheme may be made simultaneously along with the main loan application for project finance. The assistance is granted free of interest and a nominal service charge of 1% p.a. is levied on the amount outstanding under the assistance.

6. State Industrial Development Corporations (SIDCs)

SIDCs were set up in 1960s and 1970s. These were established as wholly-owned undertakings of the State Governments under the Companies Act, 1956 or autonomous corporations under specific State Acts. Different States have set up the State Industrial Development Corporations with a view to improving the growth of industry in their States. These corporations operate as per the Guidelines issued by State Governments. There are 28 SIDCs operating in our country. They provide assistance to small and medium units and projects costing up to Rs. 10 crores.

Functions of SIDCs

i) They promote and develop industries by activities like project identification, preparation of project report, selection and training of entrepreneurs.

ii) They provide term loans to industries.

iii) They grant incentives and subsidies on behalf of the Central and State Governments.

iv) They act as agent of IDBI, SIDBI and thereby provide the benefit of seed capital scheme.

v) They provide risk capital to entrepreneurs by way of equity participation.

vi) They develop industrial area by providing infrastructural facilities.

7. State Small Industries Development Corporations (SSIDCs)

SSIDCs are State Government undertakings responsible for catering to the needs of the small, tiny and cottage industries in the States/Union Territories. They undertake a variety of activities for development of the small sector. At present, there are 18 SSIDCs in operation.

Functions of SSIDCs

i) They extend seed capital assistance on behalf of the State Government.

ii) They procure and distribute scarce raw material.

iii) They provide machinery on hire-purchase basis.

iv) They provide assistance for marketing of the products of small scale units.

v) They provide managerial assistance to production units.

8. District Industries Centres (DICs)

DICs have been established in every district. The objective of establishing such centres is to develop small and village industries. They collect information about the availability of raw material and make arrangements for machinery and equipment, marketing research, credit facilities etc. for the development of small units in the district. They identify the potential borrowers in the small sector and sponsor their loan applications to the banks operating in the district. Under the Prime Minister's Rozgar Yojna Scheme (PMRY), DICs are assigned the task of identification of beneficiaries and implementation of the Scheme in the district.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write the full forms of the following Institutions:

   i) IDBI

   …………………………………………………………………………...

   ii) SIDBI

   …………………………………………………………………………...

   iii) NABARD

   …………………………………………………………………………...

   iv) SFC

   …………………………………………………………………………...

2. Match the following:

Column I	Column II
1. SFC	A) Apex level national institution in small sector
2. SIDCs	B) Delhi Financial Corporation
3. SSIDCs	C) Identification of borrowers in a district
4. SIDBI	D) Small, tiny and cottage industries
5. DICs	E) Twenty Eight

9.5 EVALUATION OF THE SOURCES OF FINANCE

The sources of finance as discussed above can be broadly divided into owned capital and borrowed capital. Both the sources have their own advantages and disadvantages. Even, for availing of borrowed capital the businessman may have to evaluate among the various available options and choose.

Advantages of Owned Capital

i) *Supply of long term capital:* The businessman obtains funds on long term basis. Owned capital provides long term investment.

ii) *Control:* The businessman maintains full control over his business. He has full rights to take decisions without interference from any outside person. Thus, he commands control over his business.

iii) *No charge on assets:* The businessman is not required to keep his assets as security with any institution so long his own capital is used in the business. Consequently, he can offer the assets of the firm to other agencies for raising loan in case he is in need of additional capital besides his own.

iv) *No repayment of liability:* Owned capital is not required to be returned to any body as in the case of loan which is required to be repaid over a period of time.

v) *No fixed cost:* Owned capital does not carry any fixed rate of return as in the case of a loan where interest is required to be paid on periodical basis.

Disadvantages of Owned Capital

i) *Investment of the personal savings:* In case a businessman has invested his own money in the business, a large chunk of his personal savings goes away. Therefore, not much is left for his rainy days.

ii) *Limited scope of expansion:* With his owned capital invested in the business, a businessman has limited scope of expansion. This is so because he can commit his own resources to a certain extent and beyond that he will have to borrow from outside sources.

iii) *Danger of over-capitalisation:* Use of owned capital may lead, at times, to over-capitalisation. This is so because the businessman is free to invest as much capital as he can. At times, the capital invested is more without being put to productive use. In that case the rate of earning is less in comparison to the capital invested.

Advantages of Borrowed Capital

i) *Availability of funds:* The businessman obtains the funds which are not available through owned capital.

ii) Long term source: Outside funds such as long term loans from banks serve as the source for investing in fixed assets.

iii) Scope for expansion: A businessman can think of expanding his business because with the help of borrowed money further resources are available which can be used in modernization and diversification of the business.

iv) Tax Benefit: Interest paid on borrowed capital is an expenditure which is deducted from the profits liable to income tax. The loans thus provide tax benefit to the businessman.

v) Non-interference in the management: The banks generally do not interfere in the management of the business.

Disadvantages of Borrowed Capital

i) *Financial burden:* The businessman is required to pay the interest on the loan regularly at a fixed rate. This results in the creation of financial burden if the enterprise is running at a loss.

ii) *Charge on assets:* The loans are generally secured by pledging the assets as security. Owing to the pledging the assets do not remain free.

iii) *Borrowing capacity:* Ideal debt-equity ratio is 2:1. Excessive borrowing reduces capacity to borrow and therefore the businessman is unable to borrow after a certain limit.

Factors Affecting the Choice of the Source of Loan

Following are the factors which should be evaluated while making a choice about the source of availing loan:

i) *Rate of interest:* Interest is an expense for the firm to be paid on regular basis whether the business earns profit or not. This reduces the profits of the firm. Therefore, the businessman should enquire as to which financial institution is charging the lowest rate of interest before taking a decision to avail of loan from a particular institution. He should opt for that source only where the interest burden is the lowest.

ii) *Repayment period:* The businessman should evaluate the various sources of loan from the point of view of repayment terms. The banker/institution who provides longer repayment period for the similar loan should be preferred.

iii) *Margin requirement:* Every lender insists upon minimum contribution as margin from the side of businessman. However, margin requirement may differ from bank to bank. Thus, a businessman should negotiate the loan proceedings with the bank which offers lower margin requirements.

iv) *Processing charges:* Every financial institution imposes some charges for processing the loan proposal, known as processing charges. It is also one of the factors which should be considered while evaluating a loan. Lower processing charges should be preferred. At the same time, it should be seen that there is no hidden cost involved in a particular loan proposal.

v) *Time-period involved in sanctioning the loan:* The banker who takes lesser time in sanctioning and disbursing the loan should be preferred. In the case of some banks even branch managers are empowered to sanction loans whereas in the case of others, the sanction comes from the higher authority. It is but natural that the branch manager, if empowered, can sanction loan at the earliest whereas if the sanctioning authority is other than the branch manager, the sanction will take much longer time.

9.6 MATERIAL: ITS PROCUREMENT AND IMPORTANT CONSIDERATIONS

Material is one of the five M's of business. With the help of raw material a product can be developed. After the product is sold in the market generation of revenue starts. It is pertinent to note that raw material is the first element in the cost of the product. A proper control over the material is a must right from its procurement till it is consumed in developing the product. In the following paragraphs important aspects relating to materials are discussed.

Principles of Purchasing

Material is procured through the process of purchasing. Therefore, a proper control over purchasing is necessary. Following points, known as five R's of best buy, are the main principles of purchasing material:

1. Right Source
2. Right Quantity
3. Right Quality
4. Right Price
5. Right Time

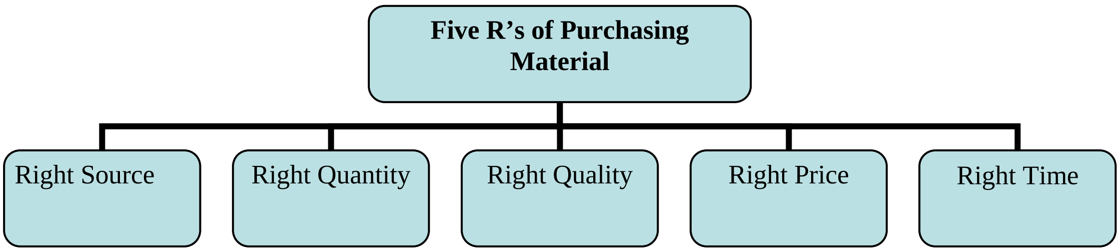

Figure 9.4: Diagrammatic representation of five R's of purchasing material fog

Let's now discuss the five R's in detail.

1. Right source

Right source of procuring raw materials indicates the suppliers/sellers from whom the material can be procured. If the source of procuring material is right we can hope to procure material of right quality in right quantity at right price and at right time. In other words, if there is right source the access to other R's of best buy can easily be made. The following points should be kept in mind while making a choice for the right source:

i) *Location of the supplier:* The businessman should see that the supplier is preferably located near his business site so that heavy spending on transportation is avoided. In fact, geographical location of the supplier has a lot of bearing on the procurement of material.

ii) *Financial position of the supplier:* The businessman should keep in mind that the financial position of the supplier is sound. If the supplier is of sound financial position, he will keep the material always in stock otherwise he may always demand advance payment as and when the order is placed and supply the material after a gap of certain period. In other words, ready supply may be a problem.

iii) *Terms of Supply:* The businessman should procure the material at terms which are beneficial to him. Thus, the ideal supplier will be the one who offers the best terms of supply.

iv) *Production facilities at supplier's end:* In case the supplier is producing the material whether production facilities at his end are capable enough to produce material as and when demanded. The businessman has to keep this aspect also in mind, while making a choice of the right supplier.

2. ***Right quantity***

   Procurement of material in right quantity is another consideration to be kept in mind by the businessman. Right quantity of material to be purchased shall depend upon the (i) raw material required for the production during the year; (ii) time required in getting the supply of the material; and (iii) the quantity of material which the businessman can carry at a particular point of time i.e. average material required. The businessman shall have to decide as to how many orders should be placed in a year so that per order cost is the minimum. Bulk quantity can be purchased at a discount but in that case, the amount of capital invested in bulk purchase shall be more and at the same time the storing cost of the material shall also be more. Thus, a right balance is to be maintained and optimum quantity is to be purchased.

3. ***Right quality***

   Right quality of the material indicates that it will suit the requirements of the product. Quality will relate to the size, shape, appearance, colour, strength etc. of the material. According to the product to be produced, the businessman should decide the right quality of the material.

4. ***Right price***

   Right price of the material indicates that qualitative material is available in right quantity at that price. Right price may not be the lowest one but it should be as near to the lowest side as possible. Right price also means that the supply is available without delay, reasonable services are provided by the supplier and transportation cost in getting the material delivered at the door-steps of the businessman is the minimum. It may happen that though the price of the material is very low but transportation cost of bringing the material to the site is very high. Thus, the overall cost to be incurred is much higher than the cost at which the material is available locally. In this case local price is the right price.

5. ***Right time***

   Material should be available to the businessman at the right time. It means whenever the material reaches the re-order level, the supply should be available before there is stock-out. Further, supply should be available without keeping excessive stock. In other words, right time of purchasing indicates that there is no problem relating to piling up of stock or because of shortage of stock the production is to be stopped for some time.

Purchase Procedure

The job of purchasing material should be done by Purchasing Department under the supervision of Purchase Manager if the size of the concern allows. Purchasing of material involves a series of steps. Let’s now discuss these steps one by one.

1. *Purchase requisition*

   The purchase process begins with the receipt of a purchase requisition by the purchasing department. The requisition contains particulars regarding quantity, quality, date by which the purchase of material is required etc. A specimen of purchase requisition form is given below (Table 9.1):

Table 9.1: Specimen of purchase requisition

ABC Bros.

Address:----------------------

Purchase Requisition

No. **Date-------------**

Please arrange to purchase the following items by ------------2005

Code no. of the article	Quantity to be purchased	Description of the article	Stock in hand	Previous order	
				No. with date	Name of the supplier

Signature--

(Name of the authorised signatory)

Designation

2. *Inviting quotations*

   After receiving the purchase requisition, the purchase department contacts the various suppliers and invites quotations from them. A quotation indicates the price, quantity, quality and other terms and conditions of purchase.

3. *Purchase order*

   The purchase department will scrutinize the quotations received from various suppliers. The person who is willing to supply the material of right quality at the right price should be preferred. A purchase order will then be prepared authorizing the supplier to supply the quality material at the agreed terms and conditions (Table 9.2)

Table 9.2: Specimen of purchase order

ABC Bros.
Address:----------------------

Purchase Order

No. **Date-------------**

Please arrange to supply the following items by ------------2005 as per the agreed terms and conditions stated overleaf:

S. No.	Description of the article	Quantity	Rate per item (in Rs.)	Amount (in Rs.)	Remarks

Signature---
(Name of the authorised signatory)
Designation

4. *Receiving of material*

   The Receiving Department will now receive the goods, unpack them and verify the contents of the packages with the consignment notes sent by the supplier. Discrepancies, if any, are then brought to the notice of the supplier for taking corrective action.

5. *Initiating payment*

   The copies of purchase requisition, purchase order, invoice etc. are sent to the Accounts Department. This Department checks the calculations etc. and thereafter, issues a cheque to the supplier towards payment.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Mr. Gupta, Manager of Receiving Department, on examination finds that out of 100 containers of mustard oil supplied by M/s. Nagpal & Co., five are leaking. Write the appropriate action to be taken by him.

   ……………………………………………………………………………........

   ……………………………………………………………………………........

2. Arrange the following steps of procuring material in proper sequence:

   i) Inviting quotations
   ii) Receiving purchase requisition
   iii) Initiating payment
   iv) Placing purchase order
   v) Receiving of material

9.7 LET US SUM UP

Once the businessman decides as to which line of business he should enter into, the next significant task for him is to organize various resources for his business. Besides other resources, he has to arrange for finance and material. Finance is needed to start a business and to expand, renovate and modernize it. A businessman needs both fixed capital (for purchasing fixed assets) and working capital (for meeting day to day financial requirements of business). Long term finance can be obtained through owned capital and retained profits ploughed back in the business. Further, funds can also be borrowed from friends and relatives and loans can be obtained from Commercial banks, National-level Financial Institutions and various State-level Financial Institutions as well. Short term finance can be obtained through various sources like bank overdraft, cash credit, discounting of bills of exchange, short term loans, trade credit from suppliers, assistance from Co-operative Credit Societies etc. There are certain specialized financial institutions like IDBI, SIDBI, NABARD, various SFCs, SIDCs, DICs which are involved in providing loans to the industries at attractive terms and conditions. A businessman should thoroughly evaluate the various sources of finance before committing funds in the business. Material is needed to develop a product. A businessman has to apply the five R's of the best buy. For procuring material, the businessman should develop and follow the right kind of purchase procedure.

9.8 KEY WORDS

Collateral security : Secondary security demanded for sanctioning loan, in addition to the primary security.

Preliminary expenses : Expenses incurred by a company before its formation.

Commitment charges : Charges levied by the bank for not using the sanctioned limit.

Debt-equity ratio : A ratio which establishes relationship between debt and equity. Normally, loan equivalent to double the equity can be raised.

Deferred payment guarantee : A kind of guarantee given by a financial institution to the supplier of fixed assets like machinery that the payment of instalments shall be made on due dates.

9.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. i) Owned funds
   ii) Friends and relatives
   iii) Friends and relatives
   iv) Commercial banks
   v) Owned funds

2. i) Working capital
   ii) Fixed capital
   iii) Fixed capital
   iv) Working capital
   v) Fixed capital

3. i) Trade credit
   ii) Accrual account
   iii) Indigenous banker
   iv) Overdraft
   v) Discounting of bill of exchange

Check Your Progress Exercise 2

1. i) Industrial Development Bank of India
   ii) Small Industries Development Bank of India
   iii) National Bank for Agriculture and Rural Development
   iv) State Financial Corporation

2.

Column I	Column II
1. SFC	B) Delhi Financial Corporation
2. SIDCs	E) Twenty Eight
3. SSIDCs	D) Small, tiny and cottage industries
4. SIDBI	A) Apex level national institution in small sector
5. DICs	C) Identification of borrowers in a district

Check Your Progress Exercise 3

1. **Hint:** i) Immediately after examination, informing the supplier (i.e. M/s. Nagpal & Co.) about the leakage of five containers.

   ii) Not to pass the bill for payment till the satisfactory action is taken by the supplier.

2. i) Receiving purchase requisition
   ii) Inviting quotations
   iii) Placing purchase Order
   iv) Receiving of material
   v) Initiating payment

9.10 SOME USEFUL BOOKS

1. Desai, Vasant (1998) Dynamics of Entrepreneurial Development of Management; Himalaya Publishing House, Mumbai.

2. Gupta, C.B. and Khanka, S.S. (2004) Entrepreneurship and Small Business Management; Sultan Chand and Sons, New Delhi; Fourth Ed. Reprint.

3. Maheshwari & Mittal (2002) Cost Accounting, Theory and Problems; Shri Mahavir Book Depot, New Delhi, Twentieth Ed.

4. Mitra, Bidani and Kumar, Promod (1998) Bank Finance for Industry; Vision Books, New Delhi.

5. Nabhi Publication (2004) How to Borrow from a Banking and Financial Institution; Nabhi Publications, New Delhi.

9.11 ASSIGNMENTS

1. Kotak Enterprises wants Rs. Ten lakhs to invest in stock. Under which type of capital his loan application shall be considered by the bank.

2. Explain the various short term sources of finance.

3. Explain the various long term sources of finance.

4. "Working capital is needed because of the existence of operating cycle." Comment.

5. Mention the various functions of State Financial Corporations.

6. How do the commercial banks contribute towards the development of an economy.

7. Should the indigenous bankers be eliminated altogether? If yes, then why are they still existing in our society.

8. Write correctly the following Government sponsored schemes:

   i) Swarna Jayanti Gram Swapan Yojana
   ii) Prime Minister's Rojana Yojana
   iii) Swarna Jayanti Shatabdi Rojgar Yojana

9. M/s. Kohinoor Bros. are interested in purchasing 500 Kgs. of sugar. Explain the purchase procedure which shall be followed by them.

10. Purchase requisition is a first step of purchasing raw material. Mention the remaining steps of procuring the material.

11. Complete the following Specimen of Purchase Requisition Form of Vikalp & Co.

Vikalp & Co.
Address:-----------------------

Purchase Requisition

Signature---
(Name of the authorised signatory)
Designation

12. Complete the following operating cycle by filling the correct words:

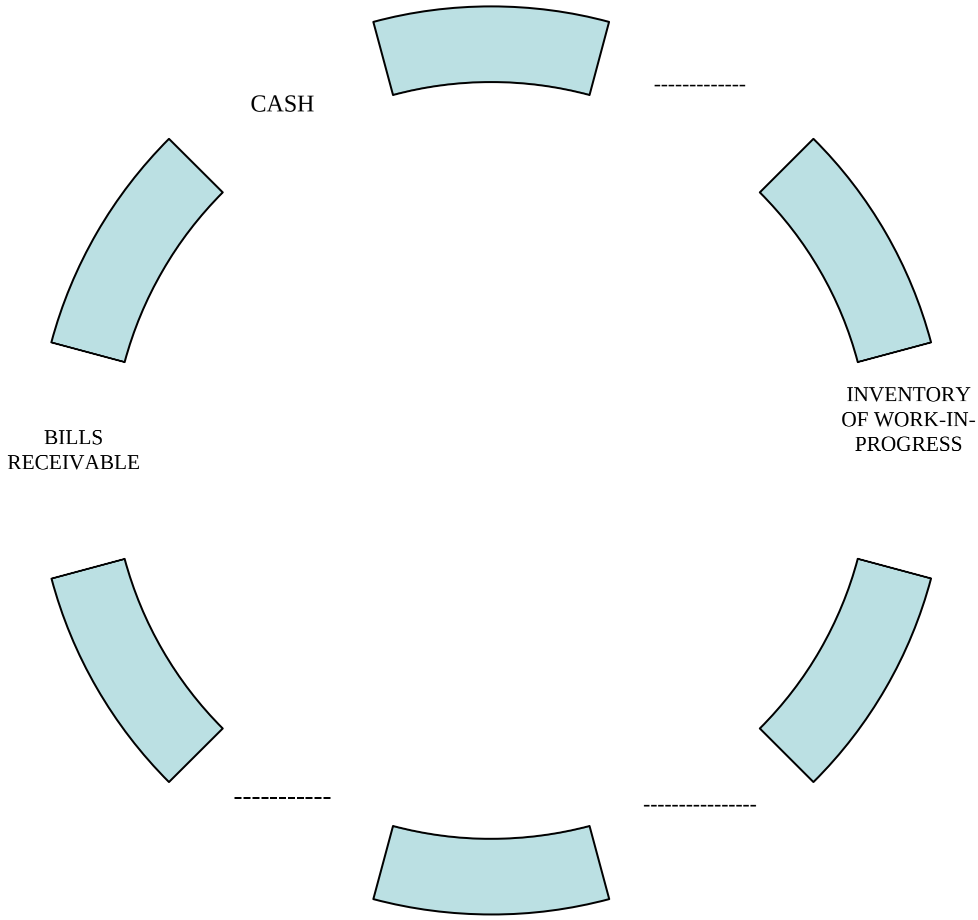

Figure 9.5: ………………………………………………………………….

UNIT 10 UNDERSTANDING THE COMPONENTS FOR MARKETING MIX

Structure

10.0 OBJECTIVES

After studying this unit, you should be able to:

- know about the meaning of marketing mix;
- understand the importance of marketing mix;
- identify various elements of product mix;
- comprehend the pricing of the product;
- understand the various aspects of promotion; and
- know the physical distribution of goods.

10.1 INTRODUCTION

Human needs are unlimited. Human beings need different types of commodities to satisfy their needs. A businessman therefore, engages himself in manufacturing different types of products and services. Marketing can be said to be a process involved in the exchange of goods and services for payment of their cost.

Marketing refers to all those activities which help in directing the flow of goods from the manufacturer to the ultimate user. In other words, the process of marketing leads to the exchange of goods and services through which the needs of the consumers are met.

A businessman has to undergo various activities and to decide upon various issues in order to reach his target. For this purpose, the firm must develop the product, determine its price, inform the potential customers about the product, and make it available to the present and potential customers. All these activities signify that the businessman has to put together all the tools at his disposal in combination so that his objective of selling the goods and services with profitable margins is realised. In the light of this view, a businessman can be thought of as an assembler or mixer of ingredients. The success of the businessman depends on how well these ingredients are assembled.

Marketing mix is nothing but the ingredients or the tools or the variables that the businessman mixes in order to interact with a particular market. Marketing mix has been discussed briefly in Block 2 (Unit 3) – "What does Market Involve", keeping in view the requirements of that Unit. In this Unit, marketing mix has been taken up in detail.

10.2 MEANING OF MARKETING MIX

Meaning and Importance

Marketing mix is a term which is usually used to refer to a particular combination of marketing variables which are controllable by an enterprise. Marketing mix can be regarded as the core of any business firms marketing system. According to Philip Kotler "Marketing mix is the set of controllable variables that the firm can use to influence the buyers' response". In simple words, marketing mix can be said to be the set of marketing tools that the firm uses to pursue its marketing objective in the target market.

Marketing mix comprises decisions taken in the following four important areas:

1. Product
2. Price
3. Promotion
4. Physical distribution i.e. Place

The businessman has to prepare various strategies relating to the aforesaid elements i.e. in the fields of Product, Pricing, Promotion and Physical distribution. The last element i.e. physical distribution is also referred to as 'place'. These four elements are popularly called four P's of marketing mix.

Following diagram depicts the four elements of marketing mix.

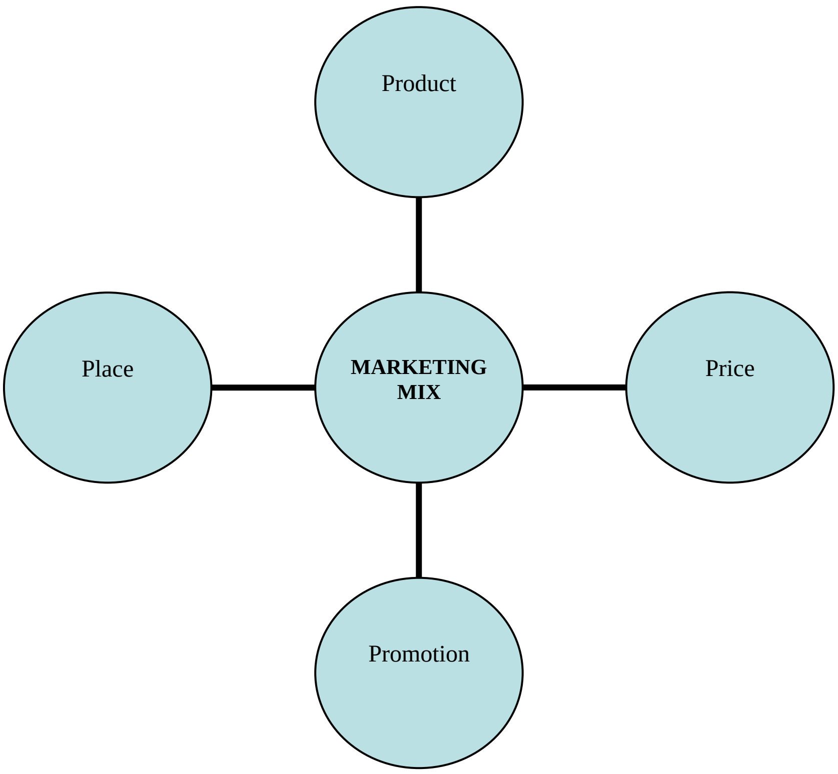

Figure 10.1: Diagram depicting four elements of marketing mix

Importance of Marketing Mix

A judicious mix of the four P's is very important for satisfactory marketing of goods. It will lead to consumer satisfaction, on the one hand and profit maximization, on the other. Marketing mix is thus, the main building block of marketing efforts of a firm. The importance of marketing mix is explained as under:

1. It leads to increase in sales and profits of the business firm.
2. It represents an integrated approach to marketing because a balance is maintained among its inter-related elements.
3. It serves as a linking-pin between the firm and its customers.
4. It helps in maintaining equilibrium between the business firm and its marketing environment.

10.3 MARKETING MIX – PRODUCT

Product mix is one of the important elements of marketing mix. The product element of marketing mix refers to a combination of various features relating to a product which is offered for sale. It signifies the product offered to the customer. It involves decisions concerning:

- Nature of the product
- Features of the product
- Branding
- Packaging
- Labelling
- Guarantees & warranties
- After-sale services

The above are also called sub-elements of product mix. Let's discuss these sub-elements of product mix one by one.

I) The nature of product

The details of nature and character of the product which are contained in the mix are related to:

a) *Product line:* It refers to a group of products within a product class e.g. in the case of Amul Co-operative Society, butter constitutes one product line, cream constitutes another, milk a third one; and so on.

b) *Product width:* The width of the product mix denotes the number of product lines that the businessman offers to the market. For example, Amul has wider product mix whereas MDH (Mahashya Di Hatti) has narrower product mix.

c) *Product length:* It refers to the number of product items that are carried in a product line. The length of product line denotes the number of items in the line e.g. Amul carries a number of product items in butter line – it offers 'white butter' and 'salted butter'. Similarly Amul cheese may be 'cheese spread' or 'sliced cheese'.

d) *Product Depth:* It refers to the total number of variants that are offered of each product item in the product line. In the case of Hindustan Lever Limited the soap Lux may be Pink, white or Lux international.

II) Features of a product

The decisions regarding features of a product are mentioned below:

- *Size:* The size of the product should be easy to handle. It should be convenient to carry and to use. For example, pack of Cadbury chocolate comes in manageable size.

- *Colour:* The colour of the product should be appealing. For example, the yellow colour of Brown & Polson custard.

- *Flavour:* The product should have a wide variety of appealing flavours like Priya Gold Biscuits are found in many flavours – pine-apple, elaichi, orange etc.

- *Weight:* A product should not be too bulky or too heavy. For example Saffola oil comes in one litre pack, Amul butter comes in 100 Gms. packs.

- *Durable:* A product should have a longer shelf life. For example Kissan tomato puree has a shelf life of 12 months.

- *Shape:* Solid products can be round (like Milk Bikis cream biscuits manufactured by Britannia); square (like Krack jack biscuits of Parle); rectangle (like Cadbury's Five Star chocolate) etc. In the case of liquid eatables they take the shape of their containers. For example Pepsi, Coke, Kissan sauce, Kanodia Mustard oil etc.

III) Branding

Branding is a way for an organisation to identify its products and distinguish them from those of the competitors. Branding is naming the product or giving a symbol or mark to identify the product. In other words, a brand is a name, term, sign, symbol, or design or a combination of them, which is intended to identify the goods or services of the seller. A brand distinguishes a product from similar other offerings. A successful brand is a major asset for a company. Following terms are associated with branding:

- *Brand name:* It is that part of a brand which can be vocalized or uttered e.g. Tata tea, Sunfeast cream biscuits, Harvest bread, Frooti, Rasna, Real juice, Haldiram's Navratan etc.

- *Brand mark:* It is that part of a brand that can be recognised. It is not utterable since it is in the form of symbol; design etc. e.g. Nestlé's 'Nest' or Mother Dairy's 'Drop'.

- *Trade mark:* When brand is given legal protection, it is called 'trade mark'. A trade-mark is a legal term protecting the seller's exclusive rights to use the brand name or brand mark. R in circle (i.e.*®)* is used to show that the trademark is registered. A registered trade mark of a product cannot be used by another company. A trade mark is a registered brand name. It may not be pronounceable.

Classification of brands

Brands can be classified as under:

i) *Family brand:*

Family brand is one where a business man uses only one brand name for all his products. Amul, Everest etc. are examples that follow a family brand policy.

When one name is established as a particular brand, other products get easy and instant recognition. This method is simple and economical.

ii) *Individual brands:*

This refers to a brand name given for each individual product. The firm is able to create a distinct image for each of its products. It is a costly method.

iii) *Company name*

In this case Company's name is attached with each product name. Thus, the advantage of family brand and individual branding are combined. For example, Britannia is manufacturing different types of biscuits and in each type, brand name is preceded by the company's name i.e. Britannia like Britannia Cream Treat biscuits, Britannia 50-50 biscuits.

iv) *Separate family brand name*

The firm may follow different brand names or each class of their product i.e. the products are classified in different families and brand names are given to each family.

Selecting a brand name

To develop a brand name is one of the most difficult elements in development of a new product. A good product with a mediocre name may not sell well. Following aspects should be taken into account, while selecting a brand name:

I) It should reflect some benefit and function of the product e.g. Hajmola brand name suggests digestion.

II) It should be distinctive. It should portray status, power etc e.g. Diamond Masale; Jagat Basmati Rice etc.

III) It should be easy to pronounce, spell and remember. One syllable name should be preferred e.g. Tata Tea, Amul butter etc.

IV) It should be capable of being registered and protected legally. It should not be closely linked to an existing brand.

V) It should be short e.g. Lijjat papad.

Advantages of branding

I. Towards producers

a) It creates a new market due to its distinct identity.

b) It becomes easier to advertise the product.

c) New products can be added due to high sales and profits.

d) The price of branded product can be easily increased, once the brand becomes popular.

e) Less commission is offered to the intermediaries.

II. Towards customers

a) It is easy for the customers to recognise the product.

b) A feeling of satisfaction is created due to repeated use of the branded product.

c) The consumers always get a branded product of good quality.

d) Branded products are easily available at the retail outlet.

e) Branded products are made available at a particular price.

IV) Packaging

Packaging refers to all the activities involved in designing and producing the containers or wrappers for a product. For example, rice is packaged in jute bags or plastic bags, ghee is packaged in plastic containers.

A package may be primary package or secondary package. A primary package refers to the products' immediate container. For example, small plastic pouch in which masale are packed. A secondary package is the additional layer of protection. It is generally removed and thrown once the product is ready for use. For example, card-board box of masale on which name of the product and the company is mentioned.

Kinds of packaging

i) Family packaging

A firm may adopt family packaging for all its products. Family packaging gives a common feature of appearance on all packages i.e. packaging will be similar for all the products.

ii) Re-usable packaging

A re-usable packaging can be used again for any other purpose. For example, usually house-wives store spices or pickles in 'Horlicks' or 'Boost' bottles; drinking water in 'Rooh-Afza' bottles etc..

iii) Multiple packaging

Several units of the same product are placed in one container. It is suitable for sale of small items. For example, several biscuits are placed in a single wrapper; several pieces of 'Britannia cakes' are placed in one package etc.

Material used in packaging

Different kinds of products are packaged in different types of material. Some of the examples are given below:

- Fruits are packaged in wooden boxes or card-board boxes or straw baskets.
- Processed food or oil is packaged in metal containers.
- Rice, Ghee, Chocolates etc. are usually packaged in plastic pouches or plastic boxes or plastic wrappers.
- Paper with wax coating is used to package toffees.
- Glass is used to package cold drinks, pickles, sauces, vinegars etc.
- Aluminium foil is used to package tea, coffee, toffees etc.
- Wheat is packaged in jute sacks.
- Tetra pack is used for packaging fruit juices, fruit drinks etc.

Forms of package

A package can take many shapes. Following are the examples:

- Fruit jelly is packaged in a tube form.
- Cold drinks are generally packaged in a bottle form of packaging.
- Tea, spices etc. are generally packaged in small unit packages like 250 gms package, 100 gms package etc.
- Candy, soups, pan masala etc. are usually packaged in sachets.
- Jars are used to package Desi Ghee, edible oil etc.
- Refill packs are used to package coffee, chocolate powder, tea etc.
- Cans are used to package fruit juices, cold drinks etc.
- Bags are used to package flour (atta), rice etc.

Benefits of packaging

- It is an effective advertising medium.
- It provides space in which the product can be contained.
- It helps in keeping the product safe from pests, rodents, moisture, rain etc.
- It helps in storage.
- It helps in product differentiation.
- It helps in increasing sales.
- It increases the shelf life.
- It ensures visibility of the product if the material is transparent.
- It ensures easy handling of the product.
- It makes the product attractive.
- It makes brand of a product popular.

- It protects the goods from pilferage and adulteration.
- It can be re-used.

V) *Labelling*

The term labelling means putting labels on the package or the product. A label is a small slip to provide information to the customers e.g. the name of the product, price etc. A label may be a piece of paper, printed statement, imprinted metal or leather which is attached either to the package or to the product. The label describes the nature of the product, contents of the package and other information like price, date of expiry, batch number, weight etc.

A label is a strong sales tool and an integral part of the point of purchase advertising. Labels are designed to help promoting a product.

Functions of labelling

Labelling serves the following functions:

- Identification of a product is easy for the customer.
- The manufacturer is able to grade the products into different categories, e.g. Hindustan Lever Limited (HLL) sells different types of tea under yellow, red and green label.
- It is a carrier of information.
- It provides information, which is mandatory by law.
- It attracts the buyers and draws them to buy the product.
- It helps in comparing the product.
- It leads to easy trading for retailers.

Features of a good label

- It should supply sufficient information.
- It should be easy to locate and read.
- It should be simple to understand.
- It should be colourful and attractive.
- It should help to make a buying decision.
- It should contain statutory information, if any.

VI) *Guarantees and warranties*

Guarantee is a policy adopted by the manufacturer with regard to his products in case any is found defective. It is an obligation assumed by the seller in which he promises the buyer that he will get certain services in future, including replacement, repairs etc.

Warranty is an assurance of quality, service and performance given by the producer to the consumer. It points out the responsibility of the businessman for repairs, service and maintenance in the case of consumer durables.

VII)After sales service

After-sales service, as we all know, is required after the product has been sold. It is an important aspect of a marketing transaction. After-sales service covers repairs, changing parts at lower charges etc. These services are provided so that the customer is satisfied.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Under which category of branding do the products of 'KISSAN Brand' fall:

   i) Family branding
   ii) Individual branding

2. To which type of packaging 'Tata salt' belongs:

   i) Primary packaging
   ii) Secondary packaging

3. Write the name of the material in which 'Kanodia Brand' 'one kg mustard oil' is packaged:

   i) Plastic; or
   ii) Tin

4. The package of 'red chillies' is an example of multiple package or re-usable package.

5. The label of 'Rex Baking powder' carries information regarding directions for use, net weight, etc.

   i) Yes
   ii) No

10.4 MARKETING MIX – PRICE

The Price element of marketing mix refers to the price to be charged by the businessman. It is the source of revenue for the businessman and cost for the customer. Pricing is one of the most important decision-areas of marketing. This is the only area from where revenue is earned by a businessman. Pricing is crucial to profit as well. Price is the exchange value of a product. A low or a high price may mean success or failure for a businessman. Pricing is the process of translating the value of a product or service in terms of money. Prices not only determine what a businessman will get in return for the goods he has produced but it also has an impact on future production and marketing.

Importance of Pricing

- Price acts as a regulatory mechanism by means of which the buyer and the seller come to a mutually satisfactory understanding.
- Price determines the sales volume.
- Price determines the profit margin.
- Price affects the competitive position.
- Price affects the market share.
- Price determines the purchasing power and standard of living for a customer.

The various decisions taken by a businessman under price mix are as under:

I. Pricing policy

II. Pricing Strategies

III. Discounts and Allowances

Let's now discuss these decisions in detail.

I. Pricing policy

A product has to be priced scientifically. Intuition has no place in this process. Pricing decisions have to be taken taking into account several factors. These factors are discussed as under:

Factors influencing pricing policy

- *Consistency:* Pricing has to be consistent with overall objectives of the firm, e.g. the firm's objective may be profit maximization or to achieve a high turnover. Accordingly, it may be a higher price or lower price.
- *Public image:* If the public image of the product is high the price may be kept high.
- *Purchasing power of the consumers*: If the purchasing power of the consumers is low, the price should be kept low.
- *Ability to postpone purchase:* If the consumer can think of postponing the purchase of a particular product, the price of such product should be kept low.
- *Pricing policy of the competitors*: The businessman should fix the price keeping in view the pricing policy of the competitors.
- *Availability of substitutes:* The price may be kept higher in case there is no substitute for the product available in the market.
- *Cost of production:* The price fixed should be such as would recover all the costs including a fair return to the businessman.
- *Demand and Supply:* If the demand of the product is higher than its supply the price may be fixed at a higher level. In case supply exceeds the demand, the price should be fixed al low level.

- *Current fashion and tastes:* If the product matches the current fashion and tastes, a high price may be fixed.

- *Price control measures:* The prices of certain products are controlled by the government. The businessman should fix the price keeping in mind the prevailing policies of the government.

II. Pricing strategies

Pricing strategies provide a framework within which pricing decisions can be taken systematically to achieve the pricing objective. Following are the different pricing strategies which may be adopted by the firm:

i) Skimming pricing

This is usually adopted to price a new product. A very high price is set in the beginning. The cream of demand may be skimmed and huge profits can be made. In other words, the product is offered to some buyers who are ready to pay much higher price than the others. This may be because the product has high present value to them or they are insensitive to price. Later on price may be reduced to tap other segments of the market.

ii) Penetrating pricing

In this case a low price is fixed to go deep into the market immediately. Due to low price the brand becomes popular and thereby market share can be maximized. It is an aggressive pricing strategy.

iii) Price-discrimination pricing

In this case product is sold at two or more prices. Different customers pay different amount for the same product. Price can be different on the basis of different locations as well.

iv) Going-rate pricing

Under this method, the firm sets its prices on the basis of what its competitors are charging. This system is preferred to keep harmony within the industry.

v) Target pricing

In this method, the businessman tries to determine the price that would give it a specified target rate of return on its total cost at an estimated standard volume.

vi) Cost-plus pricing

Here price is set on the basis of adding some fixed percentage to the unit cost. A cost estimate is done and a margin is added thereto for covering the marketing expenses and profits.

vii) Loss-leader pricing

Here the business firm sells some popular product at a very low price. The aim is to attract the customers to enter the shop. The customers who come to buy that item will stay on and buy other products which are regularly priced. The products which are sold at low price are known as loss-leaders and therefore, the pricing strategy involving the use of loss-leaders is called the 'Loss-leader Pricing'.

viii)Prestige pricing

Under the system of prestige pricing, the price of the product is usually kept high on the basis that a high priced product will be sold better as the customer will think that quality of the product is reflected in the price.

ix) Odd pricing

Under this system of pricing, an odd amount is set for the product e.g. Rs. 599.95 in place of Rs. 600. This pricing gives a psychological feeling that the price is at a lower rung and the buyer is motivated to buy.

x) Marginal pricing

Here price is set to cover the marginal cost only and not the total cost. This method cannot be followed for a long period of time as it ignores the fixed cost.

III. Discounts and allowances

Discounts and allowances are granted by the businessman either to the customer or to the wholesalers and retailers. Discounts and allowances are offered with a view that the other person will provide some benefit by performing some marketing activities the value of which will be equal to the amount of the discount or allowance.

Types of discount

- *Trade discount:* It is allowed by the businessman to the wholesalers and retailers on purchase of goods in large quantity. The amount is deducted from the list price itself.

- *Quantity discount:* It is allowed by the businessman to a customer to encourage him to buy in large amount. It is offered because of a large single purchase.

- *Cash discount:* It is offered by the businessman to the wholesalers and retailers in order to get early payment. For example, when the wholesaler is required to make payment within 10 days of sale, he may be offered that if he makes payment early, say within 5 days, he will be given a cash discount of 5%.

- *Seasonal discount:* This discount is allowed by the businessman who is dealing in seasonal product. For example fans, coolers may be sold during winter season at a discounted price. Thus, he may offer discount if an order is placed during the slack season.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the following:

   i) A strategy where a high price is set in the beginning.

   ………………………………………………………………………...

   ii) An aggressive pricing strategy.

   ………………………………………………………………………...

   iii) A strategy where two or more prices are set.

   ………………………………………………………………………...

   iv) A strategy where price ends in odd amounts.

   ………………………………………………………………………...

   v) A strategy where purpose is not to get customers to buy the bargain itself but rather to buy other items as well.

   ………………………………………………………………………...

2. State true or false in Column (3):

Sl. No. (1)	Statement (2)	True/False (3)
1.	Price influences plans for future production and future marketing.	
2.	Pricing is the art of translating into quantitative terms the value of the product to the customers at a point of time.	
3.	Price affects the competitive position.	
4.	Price is used to increase sales volume to the level that matches the organisation expenses.	
5.	Pricing decisions are influenced only by public image.	

10.5 MARKETING MIX – PROMOTION

Promotion is yet another element of marketing mix. The promotion element of marketing mix refers to the activities related to the promotion of the product. The businessman has to take into account this element as well before deciding on any marketing activity. Promotion is a marketing effort done by the businessman to inform about the merits of a product or service and to persuade actual or potential customer to buy.

Promotional strategy concentrates upon letting the product reach the target market through the marketing channels. In this process the businessman needs to communicate to target market and the wholesalers and the retailers so that sales take place as scheduled and his marketing objectives are achieved. Promotion is a communication tool in the hands of a manufacturer.

Promotion mix is the combination of different forms of promotion used by a businessman. The promotion efforts are directed at informing potential customers about the availability of right product and at the right place and at the right price. The core of promotion is communication. The businessman generally chooses a combination of promotional tools to achieve desired communication effect. The various decisions taken under promotion mix are as follows:

I. Advertising
II. Sales promotion
III. Personal selling
IV. Publicity

Let's now discuss the various decisions one by one.

I. Advertising

Advertising is a paid form of non-personal presentation and promotion of ideas, goods and services by an identified sponsor. In other words the communication is directed towards a target audience by the sponsor.

Advertising is spreading the information about an idea, product or service to the people. It is said to be non-personal due to absence of face-to-face contact with the customer. Advertising has mass appeal. It can influence large section of the society. It enables the buyer to know the new product available in the market.

Features of advertising

- It is non-personal in nature.
- It persuades the buyers to purchase the goods.
- It is a paid form of communication.
- It can reach a large section of the people.
- It provides information on the products and services to the customers.

Objectives of advertising

- To inform the customers about the product.
- To build an image of the product in the market.
- To increase sales.
- To support sales promotion measures.
- To build brand loyalty.
- To fight competition in the market.

Benefits of advertising

For consumers:

- It provides information regarding price, availability, quality etc.
- Comparison with other products becomes easier.
- It acts as a guarantee regarding quality.

For manufacturers:

- It increases the sale of the product.
- It helps in easy introduction of new product.
- It establishes contact between manufacturers and consumers.
- It helps build the image of a product.
- It enables them to face competition.

Types of advertising

1. *Product advertising:* The emphasis of product advertising is to inform the customers about the product manufactured by the firm. The purpose is to create a favourable attitude of the product in the minds of the customers. Hence, a desire is created to buy that particular product.

2. *Institutional advertising:* The emphasis of institutional advertising is to build the goodwill of the firm. The aim is to build a positive attitude towards the businessman.

3. *Primary advertising:* It is one of the forms of product advertising. This type of advertising is done to build a demand for a new product.

Media used in advertising

Let's evaluate the important media of advertising.

1. *Newspaper*

   It is a form of print medium. It is a medium through which general public can be reached. The advertisements are inserted in the morning or evening editions or in Sunday edition of the newspaper. The newspaper may be circulating at a local level or state or national level. It can be an English language newspaper like Hindustan Times or Times of India or Asian News or The Hindu or a Hindi newspaper like Navbharat or Hindustan or Dainik Jagran or any other regional language.

   Advantages:

   - Newspapers have a wide circulation as national dailies cover a large geographical area.
   - They offer more flexibility as shape, size, colour and appearance of the advertisement can vary.
   - It is economical as it is cheap in comparison to other media.
   - The response of the consumers is quick.
   - Lengthy message can be transmitted through this medium.

Disadvantages:

- Life of newspaper is short.
- It may not be as attractive, for the paper used is not of good quality and printing may also not be very fine.
- Such advertisements are usually read in a hurry.
- Space allotted to the advertisement in the newspaper may be small.

2. *Periodicals*

Magazines/business journals are purchased for entertainment and information. They are published at periodical intervals like weekly, fortnightly or monthly. The advertisements can be placed in magazines like Woman's era, Femina, Outlook, India Today, Grih Shobha etc.

Advantages:

- It has a strong visual impact as it is colourful and appears on a fine quality paper.
- Such advertisements are read at convenience, in a relaxed mood as the magazine is generally read when the reader has sufficient time in hand.
- Such advertisements have long life as the magazines containing them are generally preserved and read repeatedly.

Disadvantages:

- It is costly to get an advertisement printed in a magazine.
- The advertisement may not appear at the desired time since the magazine is published periodically.
- The magazine has limited coverage.
- Lack of flexibility because changes in the contents of the advertisement may not be possible once the magazine goes for printing.

3. *Television*

As of now, TV is the widest and fastest growing medium. It creates a permanent impression in the mind of the viewers especially children.

Advantages:

- It has audio as well as visual impact.
- It is appealing.
- The advertised product can be demonstrated.
- It has wide coverage.

Disadvantages:

- It is very costly.
- Since the advertisement appears at a time which is not certain a person not watching TV at that time will miss it.

- Lack of flexibility as desired changes may not be incorporated.
- Small-sized companies cannot afford an advertisement on TV.

4. *Radio*

Radio advertising is very popular for the last so many decades. Radio is listened to by rich and poor, old and young, male and female alike.

Advantages:

- The message can reach the remotest place.
- It has wide coverage since all walks of people listen.
- It is a cheap medium of advertisement.

Disadvantages:

- Radio is only audio and has no visual impact.
- There are noise disturbances.
- It has got short message life.

5. *Outdoor advertising*

Outdoor advertising has gained popularity as an important medium in recent times. Its form can be banners, hoardings, billboards, posters, electric poles etc.

Advantages:

- It is attractive and colourful.
- Electric display of the advertisement on roadsides can be very effective.
- It builds awareness quickly.
- It has long life as there is repeated exposure.
- It catches the attention very quickly.
- Low cost.

Disadvantages:

- Limited creativity because such advertisement may contain very limited description of the product.
- The coverage is narrow as it has limited audience.
- It has a short attention span.

6. *Internet*

It is the latest form of advertising medium.

Advantages:

- It is effective.
- It is not costly.
- It is flexible as data can be changed without much difficulty.
- It can be attractive and colourful.
- It may contain lot of information about the product.

Disadvantages:

- Limited reach because advertisement can reach only highly selected audience.
- Problem of connectivity as the server may be down.
- Irregular electric supply may pose a barrier in reaching the advertisement.

7. *Film advertisements*

These types of advertisements are shown in the cinema halls before the main feature film is started or during the interval. In this case, short films or cinema slides are prepared and distributed to the cinema houses for display. The advertisement film contains pictures regarding the product and its uses along with a running commentary.

Advantages:

- It is colourful.
- The advertisement has got life-size pictures.
- It gets attention of the viewers sitting in the cinema hall.

Disadvantages:

- It has limited coverage because a handful of viewers can see the advertisements.
- The advertisement may be missed by those persons who enter the cinema halls a bit late or after the start of the feature film.
- It has short life.
- The preparation and display of advertisement is costly.

8. *Exhibitions and trade fairs*

Businessmen get a nice chance to reach the target market through various exhibitions and trade fairs organised in the cities. Good friendly relations can be built between the businessmen and the customers. Further, the customers get an opportunity to study the product, technical advantages, quality etc. The product can be demonstrated as well. This method is suitable for big manufacturers.

9. *Window display*

The goods are displayed beautifully in the windows at the entrance of the shop. The displays are made more attractive through the use of powerful coloured lights, glitters, show-cards, cut-out displays etc. Window display increases sales. The shopkeeper's time and energy in canvassing about the product are saved.

10. *Showrooms*

Showrooms are separate shops or rooms where the product line of the manufacturer is on display. The customer gets full idea of the product, price etc. A lot of literature in the form of pamphlets, booklets is also freely available. These are maintained in attractive style and goods are displayed in popular style. Showrooms are maintained only by big manufacturers, retailers or wholesalers. Immediate sale can also take place.

Factors affecting the choice of media

Following are the various factors on which choice of the medium will depend:

1. *Coverage*

   Large size of audience can be reached if media like TV, newspaper, magazine, radio are chosen. For selective coverage, film advertising or internet can be selected.

2. *Flexibility*

   A businessman may want to change or modify his advertisement. The medium like TV, magazines may pose problems in changing the advertisement. Radio, newspapers, posters, hoardings are comparatively more flexible.

3. *Cost Factor*

   Cost is an important deciding factor for the medium to be chosen. The benefits of the media should also be evaluated in terms of cost. TV, film advertisements, magazines are costly compared to newspapers or posters.

4. *Life of the advertisement*

   All the media do not have the same life. Media like TV, newspaper, radio have a very short life. People forget the advertisements after looking at it. Magazines, business journals etc. have a long life as they can be preserved by the readers. Usually, people refer to these magazines, business journals etc. even after some gap of time.

5. *Class of people*

   Illiterate people can be targeted through the medium of TV, film advertising, radio where reading is not involved. For literate people, internet, newspapers, magazines etc. are a good option.

6. *Nature of product*

   Consumer goods can be promoted through media like newspaper, magazine, radio, TV etc. whereas industrial goods can be best advertised through business journals, trade fairs, exhibitions etc.

Objections to advertising

- It forces the people to buy goods.
- It leads to extravagance as the people particularly children are induced to buy products which they may not be requiring.
- It increases the cost of the goods.
- It may misrepresent facts.
- It may confuse people.

The above points, however, are not fully valid. The consumers, now-a-days, are very vigilant and alert. They have their own mind to think. Therefore, it is rather difficult to mislead them.

II. *Sales promotion*

Sales promotion is an important communication tool in the hands of the businessman. It refers to short term incentives offered to the consumers. Sales promotion techniques draw a quick response from the target customers. It induces the customers to take the purchase decision. Sales promotion efforts are best suited for new products. In spite of all these benefits, sales promotion lacks permanence because the customer usually goes back to the earlier brand of the product which he was using earlier, after the withdrawal of the sales promotion scheme.

Objectives of sales promotion

- To increase the sales volumes.
- To make the customers try a new product.
- To increase the frequency of use.
- To gain shelf space and display at the point of sale.
- To block competition.

Techniques of sales promotion

At the level of consumers:

- *Samples:* A business firm may distribute samples of the product free of cost to a few customers. It is an expensive method. It is useful to introduce new product in the market e.g. a firm may distribute free samples of tea in a small sachet in a particular colony.

- *Coupons:* A business firm may distribute coupons to the prospective customers. The customers can save money on presenting the coupons to the designated retailers to purchase a specified product within a specified time. The time may be as short as a day or may be as long as six months. The coupons can be distributed through mail, newspapers, magazines or retailers.

- *Premium:* Premium is an offer of a product free of cost on the purchase of another specified product. It is like giving a free gift on purchase of a product e.g. a spoon is gifted along with a glucose pack of 500 gms or a cup is offered along with a beverage.

- *Price-off:* It is an offer to the consumers which promises a certain amount of money off the regular price of a product. In other words, the businessman sells the product below the normal price. There may be 10% to 20% off on the price of a specified product.

- *Contests:* Various contests are organised where a customer is required to write a slogan or complete a sentence with catchy words. For example, the sentence may start with "I like this product because-------------------------" and the prospective customer will be asked to fill in the blanks with suitable words. Attractive prices are offered to the persons chosen by the business firms.

- *Quantity deal:* Quantity deal is a new trend where a unit of product is given free of cost if more number of units are purchased e.g. one Horlicks bottle may be given free on purchase of five Horlicks bottles at a time.

- *Demonstration:* Special shows may be organised where products are demonstrated. Demonstration of a product may be outside the shop as well.

Means of sales promotion

i) *Advertising material:*

Dealers are offered advertising material like attractive pamphlets, banners etc. Due to these attractive and colourful banners on the one hand consumers become aware of the product and on the other hand the shop looks decorated and beautiful.

ii) *Contests:*

Various contests are organised by the manufacturers so that the dealers are prompted to take more interest in the selling of the product. Attractive prizes are offered which include free trip to a foreign country.

iii) *Demonstration:*

The products are demonstrated to the dealers so that they understand the working of the product. This method of sales promotion goes well with electric gadgets and mechanical products.

iv) *Buying allowance:*

The dealer gets discount on the quantity purchased. This sales promotion technique induces the dealer to purchase in bulk.

Sales promotion at the level of salesmen

The aim is to attract the salesmen as they have a direct contact with the customers.

i) *Bonus*

Salesmen may be awarded bonus in case they achieve more than a particular target given to them.

ii) *Contests*

Contests may be organised to boost the performance of the salesmen.

III. Personal selling

The other name for personal selling is salesmanship. Personal selling or salesmanship is an art to persuade people to buy. It is a face to face oral communication with the potential customers to convince them to buy the product. Here, the seller personally or through his representatives (i.e. salesmen) tries to stimulate the needs and wants of the buyer. This way he makes efforts to satisfy the needs by making a sale. In this process the needs of the buyer are met and the seller (i.e. the businessman) earns a profit. Hence, both the parties benefit.

Salesmanship is not aggressive selling. It is, in-fact, winning over. The ultimate objective of salesmanship is creation and stimulation of demand.

Benefits of personal selling

To the consumers:

- The consumers get information about the existing and the new product.
- The product is demonstrated to the consumers.
- The salesman helps the consumers in making a choice.
- The consumers are guided in purchasing and using the product which will give them maximum satisfaction.

To the businessman:

- The salesman identifies the prospective customer for the businessman.
- He helps in creating demand for the new product.
- He helps the businessman in designing a product on the basis of customers responses and the taste, attitude and preferences of the customer.
- He helps in increasing the sales and profits of the businessman.
- He enables the businessman to design or alter the sales policies.

Qualities of a good salesman

A salesman performs a number of different activities in the process of selling a product. The efficient and effective performance of sales activities requires certain qualities in the salesman. Let's discuss these qualities one by one.

I) Physical qualities

- He should possess good and sound health.
- He should possess a pleasing personality.
- He should have an impressive voice.
- He should have energy to work.
- He should have a good posture and clean dress.

II) Mental qualities

- He should be intelligent.
- He should have sharp memory and foresight.
- He should have keen observation.
- He should be imaginative and flexible.
- He should be self-confident and patient.

III) Moral qualities

- He should be honest in his dealings.
- He should be kind and empathetic.
- He should be cheerful and reliable.
- He should be loyal to both the employer and the customers.
- He should be dependable.

IV) Vocational qualities

- He should have sufficient Knowledge about the history of the company, its policies and its goals.
- He should have sufficient Knowledge about the history of the product.
- He should have sufficient Knowledge about the rival products.
- He should have sufficient Knowledge about the consumer, his background and social standing.
- He should have sufficient Knowledge about how to make effective sales promotion.

V) Social qualities

- He should have good manners.
- He should be courteous.
- He should have team spirit.
- He should be co-operative.
- He should be friendly.

Steps involved in the process of personal salesmanship

I) Pre-sale preparation

The salesman should make his foundation strong by obtaining information about the product, company, rival products, sales strategies, social background, income and age bracket of the prospective customers.

II) Locating the potential customer

He then locates the potential buyer and identifies his needs. He should also find out the product used by the customers whom he is trying to contact.

III) Approaching

He should greet the customer warmly, introduce himself politely and then introduce the product.

IV) Presentation

He should show the product to the customer in such a way that the customer feels attracted towards the product. The salesman should also describe the features and uses of the product.

V) Demonstrating

He should then demonstrate the product explaining the method to use it.

VI) Convincing the customer

The salesman should try to convince the customer regarding the quality and usefulness of the product. He should also try to remove the doubts and objections in the mind of the customer.

VII)Closing the sale

After initial negotiations, deal should be made and sale closed in a cordial manner. The product should be handed over to the customer and in return the customer should make the payment to the salesman. He should also assure the customer of service in future.

IV. Publicity

Publicity is a non-sponsored and non-paid form of non-personal presentation of ideas, goods or services by the media voluntarily. The object of publicity is to form a public opinion. It is free of cost. The business organisation is not required to make any payment to the media.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the following:

   i) A paid form of non-personal presentation and promotion of goods and services.

   ………………………………………………………………………...

   ii) A unpaid form of non-personal presentation and promotion of goods and services.

   ………………………………………………………………………...

   iii) A sales promotion scheme where a gift is given along with the product.

   ………………………………………………………………………...

   iv) A face-to-face form of oral communication.

   ………………………………………………………………………...

   v) A cheapest form of advertising having a nation-wide coverage.

   ………………………………………………………………………...

2. Give any two advantages of inserting advertisement in a newspaper.

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   ……………………………………………………………………………

3. Give any two disadvantages of radio as a medium of advertising the product.

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4. "An advertisement in TV creates a permanent impression in the mind of the viewers". Why?

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10.6 MARKETING MIX – PLACE

The place or physical distribution of marketing mix refers to the various activities which are involved in transferring the ownership of the goods to the customers. Its aim is to make products available in right quantity at the right time and at the right place. Place mix involves decisions to be taken in order to make the product available in the market. Under this concept the decisions relate to transferring of ownership to the customers and to select the channels through which the product should reach the customers. Further, the manufacturer also takes decision regarding development of distribution system for physically handling and transferring of the product through these channels.

The Following decisions are usually taken under place mix:

- Channels of distribution
- Coverage
- Transport
- Warehousing
- Inventory control

Let's discuss these decisions in detail one-by-one.

1. Channels of distribution

It refers to the path taken by the goods in their movement to the customers. It starts with the producer and ends with the consumers. In between there may be a network of inter-dependent organisations like agents, dealers, wholesalers, retailers, which help in the transfer of product.

Levels of channels

The businessman may sell the goods directly to the consumers (i.e. direct sale) or may use various channels in which case services of intermediaries are used for selling the product (i.e. indirect sale). Following are the various levels of channels starting from zero level where no intermediary is involved and ending with three-level where services of number of intermediaries are used.

a) Zero-level channel

Here no intermediary is involved between the producer and the customer. The producer directly sells to the customer. This is the shortest and the simplest channel. Goods can be sold through door-to-door salesmen, direct mail, own retail stores, tele-marketing, etc.

b) *One-level channel*

Here one intermediary is used in between manufacturer and consumer e.g. retailer. This method is popular when the retailers are big and can buy in large quantities.

c) *Two-level channel*

Here the services of wholesalers are taken along with the retailers. This channel is preferred where the producer has limited finance, market is widely scattered and the wholesalers are specialised.

d) *Three-level channel*

Here one more tier is added in way of middlemen like agents. This channel is preferred when the manufacturer cannot directly approach the wholesaler, wide market is to be reached and when the manufacturer carries a limited product line.

Factors affecting choice of channels

i) *Nature of the market:* A manufacturer of industrial products usually prefers a direct sale method whereas a manufacturer of consumer products sells the goods using various channels.

ii) *Size of the market:* A businessman sells the goods indirectly if size of the market is big.

iii) *Unit value:* The products of low unit value are sold through middleman and products of high unit value are sold directly.

iv) *Technically complex products:* A direct sale method is preferred where expert advice is required.

v) *Perishable products:* Such products usually have short channels.

vi) *Financial strengths:* The big and rich businessmen can adopt direct sale method whereas small businessmen sell their goods through middlemen.

vii) *Experience of the businessman:* A direct sale is preferred if the businessman has knowledge and experience of distribution.

2. *Coverage*

Under this the businessman decides regarding how many middlemen should be used in the distribution channel. In this respect the businessman can adopt the following strategies:

a) *Intensive distribution strategy:* Here the aim is to saturate the market. It is adopted where product is inexpensive, frequently purchased and the consumers want it in their vicinity.

b) *Exclusive distribution strategy:* Here the businessman sells his product to a particular middleman in a particular area. Exclusive distribution rights are granted to a particular distributor. This is usually adopted for the goods which may be expensive and to be consumed over a long time.

c) *Selective distribution strategy:* Here the businessman prefers to sell his product in a selected market area or through selected intermediaries. This is useful in branded goods.

3. *Transport*

Transportation helps to widen market and it bridges the distance between production and consumption centres. The various means of transportation used by the businessmen are:

- Roadways;
- Railways;
- Airways;
- Waterways; and
- Pipe-ways

Choice of the mode of transport depends upon relative cost of different modes, their speed, reliability, frequency, etc.

Transportation is a necessary function of marketing as most of the markets are geographically separated from the point of production.

4. *Warehousing*

The businessman stores the goods in the warehouse to protect them against fire, theft, pest, insects, humidity, etc. The businessman may have his own warehouse or may take on rental basis. The warehouse can be located near the place of production or near the market. A regular supply of goods to the customers at minimum possible cost is ensured through warehousing. Modern warehouses provide facilities for packing, blending, grading, labelling, etc. of the stored goods.

5. *Inventory control*

The businessman needs to maintain a particular level of stock to ensure product availability as and when the customers' demand arises. Holding of inventory involves cost of storage, cost of capital tied up in inventory, cost of spoilage, etc. Inventory control implies control over the size of inventory. The management should weigh the benefits of maintaining inventory against the cost and optimum level should be decided.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the two functions of modern warehouses.

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2. Name the channel (direct or indirect) to be adopted by a businessman in the following cases:

   i) Mr. A manufactures big ovens used for manufacturing bakery items, each costing Rs. two lacs and above.

   ……………………………………………………………………...

   ……………………………………………………………………...

   ii) Mr. B manufactures butter and cream.

   ……………………………………………………………………...

   ……………………………………………………………………...

   iii) Mr. C manufacturing spices wants to cover a large number of consumers spread over a large geographical area.

   ……………………………………………………………………...

   ……………………………………………………………………...

10.7 LET US SUM UP

Marketing refers to all those activities which direct the flow of goods from the manufacturer to the ultimate user. The term marketing mix is usually used to refer to a particular combination of marketing variables which are controllable by an enterprise. Marketing mix comprises decisions taken in the four important areas i.e. product; price; promotion; and physical distribution. These four elements are popularly called four P's of marketing mix. Product mix involves decisions concerning nature and features of the product; branding; packaging; labelling; guarantees & warranties; and after-sale services. In the case of price mix, price is to be fixed scientifically. A low or a high price may mean success or failure for a businessman. The various decisions taken by a businessman under price mix relate to pricing policy; pricing strategies; and discounts and allowances. Promotion, another element of marketing mix involves various decisions taken in the areas of advertising; sales-promotion; personal selling; and publicity. Place mix involves decisions to be taken for making the product available to the customers. Decisions taken under place mix usually relate to channels of distribution; coverage i.e. how many middlemen should be used in the distribution channel; transportation; warehousing; and inventory control.

10.8 KEY WORDS

Strategy : A specific plan devised for a campaign and to counter the moves of the competitors.

Transportation : Movement of men and material from one place to another.

Statutory requirement: A requirement which is to be followed compulsorily as per prevailing law.

10.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Family branding
2. Primary Packaging
3. Plastic
4. Multiple packaging
5. Yes

Check Your Progress Exercise 2

1. i) Skimming
   ii) Penetration
   iii) Price discrimination
   iv) Odd pricing
   v) Loss-leader pricing

2. 1. True
   2. False
   3. True
   4. True
   5. False

Check Your Progress Exercise 3

1. i) Advertising
   ii) Publicity
   iii) Premium
   iv) Personal selling
   v) Newspaper advertising

2. **Hint:** Wide coverage; Lower cost as compared to other media of advertisement.

3. **Hint:** i) Having only audio impact but no visual impact.
   ii) There are noise disturbances.

4. **Hint:** Advertisement on TV is appealing; the advertised product can be demonstrated.

Check Your Progress Exercise 4

1. **Hint:** i) Facilities for packing; ii) Facilities for blending

2. i) Direct
   ii) Direct
   ii) Indirect

10.10 SOME USEFUL BOOKS

1. Kotler, Philip: Marketing Management – Analysis, Planning and Control, Prentice Hall of India Private Limited, New Delhi.

2. Mamoria, C.B. and Mamoria, Satish (2003) Marketing Management, Kitab Mahal, New Delhi,

3. Ramaswamy, M.S. (2002) Marketing, Salesmanship and Advertising, Sterling Publishers Private Limited, New Delhi.

4. Ramaswamy, V.S. and Namakumari, S. (1998) Marketing Management (Planning, Implementation and Control-The Indian Context), Macmillan India Limited, Delhi.

5. Varshney, R.L. and Gupta, S.L. (2000) Marketing Management (An Indian Perspective), Sultan Chand and Sons, New Delhi.

10.11 ASSIGNMENTS

1. Mention the various decisions taken under product element of marketing mix.

2. Mention various advantages of branding available to the consumers.

3. Explain various kinds of packaging.

4. What is a label? Mention the qualities of a good label.

5. “Price acts as the regulatory mechanism by means of which buyer and the seller come to a mutually satisfactory understanding”. In the light of this statement explain the importance of pricing.

6. Discuss in brief the various pricing strategies.

7. Explain the factors that influence price.

8. As a publisher you have published a book titled ‘Methods of Value Addition to Various Agricultural Products’. How will you set the price of the book?

9. Why is marketing mix important for a businessman?

10. Explain the various factors which affect the decision regarding the medium of advertising.

11. You are a manufacturer of ‘Noodles’. Which media of advertising would you choose to increase your sales?

12. The life of contests as a sales promotion technique is short-lived. Do you agree? Give reasons.

13. Explain the various qualities of a salesman.

14. Explain the various factors affecting the choice of channels.

UNIT 11 PRODUCT CONSIDERATION

Structure

11.0 OBJECTIVES

After studying this unit, you should be able to:

- explain the concept of a product and its significance for an enterprise;
- identify criteria that can be used in the selecting a suitable product for your enterprise;
- select appropriate value added food products for your enterprise;
- discuss the concept of product mix and apply the same to your enterprise;
- explain how products go through a life cycle of development;
- explain the significance of branding and packaging for value added products;
- select a suitable brand name and an appropriate packaging for your value added food products; and
- identify suitable positioning alternatives for your products.

11.1 INTRODUCTION

Products are the most tangible outcome of an enterprise engaged in manufacturing. They represent the value that manufacturers create and offer to the market for consumption and usage. Product decisions are important decisions for any enterprise because they determine the line of business an enterprise has chosen for itself. This unit introduces the concept of a product and its significance to an enterprise. It also familiarizes you with related terms like the product mix, the product line and product augmentation. Selection of a suitable product line is often a major determinant of the success of an enterprise. The unit also discusses the various criteria that you should use to select appropriate value added food products for your enterprise. Like living organisms, products also go through a life cycle of introduction, growth maturity and decline which need to be managed by the entrepreneur. The Among The decisions that you have to take regarding your product are branding and packaging decisions. The unit discusses the basic inputs that must be borne in mind while considering the branding and packaging alternatives for the value added food products.

11.2 PRODUCT: MEANING AND SIGNIFICANCE

A product is anything that is offered to the market for sale and consumption and has got the potential to satisfy a consumer need or a want. Consumers buy products to satisfy their needs or wants. It is therefore, important for you to think of the product as a solution to the consumer's problem of satisfying his food related needs. When a consumer buys soap, he is looking for a solution to his need for cleanliness and personal hygiene. In addition, he may also be looking for a solution to his problem of dry skin. Among the products available in the market, those that can provide the benefits of cleaning without drying up the skin will have the greatest potential for being selected by the consumer because the consumer perceives such a product as being an ideal solution to his need to stay clean without having a dry, scaly skin. Similarly, when a mother buys a snack for a child; she is looking for the solution to her need for both safety and nutrition for her child. Only a product which provides the benefits of both nutrition and some guarantee of being a safe food product will have the potential of being selected by the mother. A product therefore, represents a bundle of benefits or attributes, which enable it to address a given customer need or want. To conceptualize a product for your enterprise, you will first have to define the need of the consumer that this product is expected to satisfy, and then identify the benefits that a given set of consumers may look for in a value added food product. Such an understanding will help you to focus on the need of the consumer as the starting point for your product idea and product concept. This understanding is important because it enables you to think of a product essentially as a solution to the consumer needs, and therefore must at all times be responsive to the changing needs and requirements of the consumer.

Activity 1

Try to identify the consumer needs that the value added food products may cater to. You may like to do this for the following categories of products

A. Jams, jellies and marmalade
B. Pickles and preserves
C. Branded spice mixes

Ask the existing consumers the reasons for their purchase of these products. In each case describe the needs that were mentioned by these consumers.

A. ………………………………………………………………………………

B. ………………………………………………………………………………

C. ………………………………………………………………………………

(**Hint:** You would find that most people mention reasons like taste and flavour in the first case while adding variety and spice to every day menu may be mentioned as reasons in the second case – All these answers give you an idea as to how new taste combinations and flavours you can actually visualize as new product ideas for the value added food products from fruits and vegetables).

You must have now understood that any given product is actually a bundle of potential benefits that you can offer to a consumer in respect of a given need. These benefits accrue to the consumer as a result of the product attributes which may be physical or psychological in nature. The physical attributes include the product ingredients, its colour, taste flavour, size, weight etc, while the psychological attributes may relate to the brand image and brand positioning in the consumer's mind.

Product classifications also help us understand how consumers behave in relation to different product classes. You may then try to identify in which class you would like to place your value added food product so that you have a general idea of what to expect from the consumers when they consider your product for purchase. Broadly, all products can be classified as consumer products and industrial products. Consumer products are those that are bought and used by ultimate consumers and in such a form that they can be used without much further processing. Industrial products, on the other hand are bought for use in manufacturing other goods or producing some services. Consumer products are further subdivided as:

Convenience goods: These are consumer goods which are frequently purchased and are bought by the consumer without making much effort in making the purchase decision or the act of buying. The consumer often has a brand in mind before he purchases the product as these are the products he may have bought many times over in the past. Common examples include newspapers, household products of daily consumption like tea, coffee, food products like breakfast cereal etc.

Shopping goods: These products are purchased after comparing the products on offer by different manufacturers and retailers. While the consumer has a general idea of what he wants he would like to compare the items on offer in the same product category before deciding what to buy. Common examples of this category are apparel, shoes, furniture etc.

Specialty goods: These are infrequently bought products and bought for their special characteristics and features, with a great degree of buying involvement. The consumer knowledge prior to product search is not very high and the purchase is characterized by fairly intensive consultation with other users and/or dealers. Examples include cars, audio visual systems, residential homes etc.

Consumer durables: These are the products which survive several uses and have a relatively long life. Examples would be products like refrigerators, fans, radio sets etc.

You would, by now, have an idea where the product category of value added food products would fit in as a product class. Being relatively perishable products, value added food products would be in the category of non-durable, speciality or shopping goods which may not relate to a basic necessity but are either part of established food habits of consumers or are bought to add special interest, variety or taste enhancement to basic fare.

11.3 PRODUCT SELECTION

Selection of an appropriate product category for your enterprise would require you to answer these basic questions:

- What is the need this product relates to?
- How is the need being presently satisfied? Are there any gaps in need fulfilment or unfilled demand that can be satisfied by your entering the market with this product? In other words, is there a need in the existing market for the value added food product that you are contemplating?
- What is the type of value that is being offered by your competitors? In what way is your proposed product likely to be different or give the consumer a reason to buy?
- Do you have the necessary skills or competency to produce the product?
- Are the raw materials for your value added food products easily accessible and available?
- What's the potential size of the market for the product; in the area in which you want to operate?
- Are special implements or machinery required for the production process of these products? Do you have the resources or the access to these implements / machinery?
- In what way is the proposed product unique or different from others in the same category already available in the market?

Before embarking upon manufacturing of any value added food product, you must get a very clear idea of the market size, the presence of competition and an assessment of the potential demand that you may be facing for the product / Products. Only if you find that a reasonable demand exists for the product, you should begin with the production of your selected value added food products.

Activity 2

Oranges being abundantly available in your area, you get an idea of selecting orange squash and marmalade as possible products for you to produce. You initially want to market the product in the local area and then go for a statewide market. What are the factors you would consider and measures to get an assessment of the market demand for your proposed product line? Using these factors, assess the local as well as the statewide demand for the proposed products.

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11.4 PRODUCT MIX DECISIONS

Let us familiarize ourselves with the common terms used in product related marketing decisions.

A single product produced by a manufacturer is termed as **product item**. When the manufacturer produces a group of related products, the terms used to describe this related group of products is **product line.** For example, jams, jellies and marmalade would constitute a product line for the value added food products manufacturer. If however, the manufacturer also decides to manufacture fruit based drinks in several different flavours, this would constitute a separate product line for him.

The term **Product mix** is used to refer to the set of all products and items that a particular manufacturer offers for the market. The *width* of the product mix defines the number of product lines offered by a producer, while the *length* of the product mix defines the number of product items offered. The extent to which the various product lines in the product mix are related in terms of production requirements, end usage and use of distribution channels defines the *Consistency* of the product mix.

Small entrepreneurs usually start their business operations with a single product item and then develop a category of related products as a product line. Their growth strategy then may comprise finding new markets for their existing product line of adding new products / lines to their product mix. It is however, important to understand that the product mix should be an optimum one, enabling you to capitalize on your resources and have a balanced growth strategy. Some of the factors as a small entrepreneur, producing value added food products, you must consider while taking your product mix decisions include the following:

1. Capacity utilization of manufacturing facilities and other resources.
2. Utilization of technical know how.
3. Cost efficiencies.
4. Possibility of improving market position through a more complete offer.
5. Profit and sales growth potential.
6. Overcoming seasonality of demand and ensuring stabilization in sales.
7. Expanding customer base and customer satisfaction.

In the context of value added food products, you may need to identify the specific attributes or features that you would like your products to have. These attributes include features like the taste, flavour, colour, their essential nature as completely natural products or products with some chemical preservatives, convenience of handling etc. You must remember that these attributes need to be responsive to the consumer tastes and preferences in the target segments chosen by you.

Activity 3

Study the product mix of a popular manufacturer of value added food products. Identify the different product lines being offered by him. Comment upon the width, length and consistency of the product mix. What in your opinion is the market advantage that he has been able to get from this offer through his product mix?

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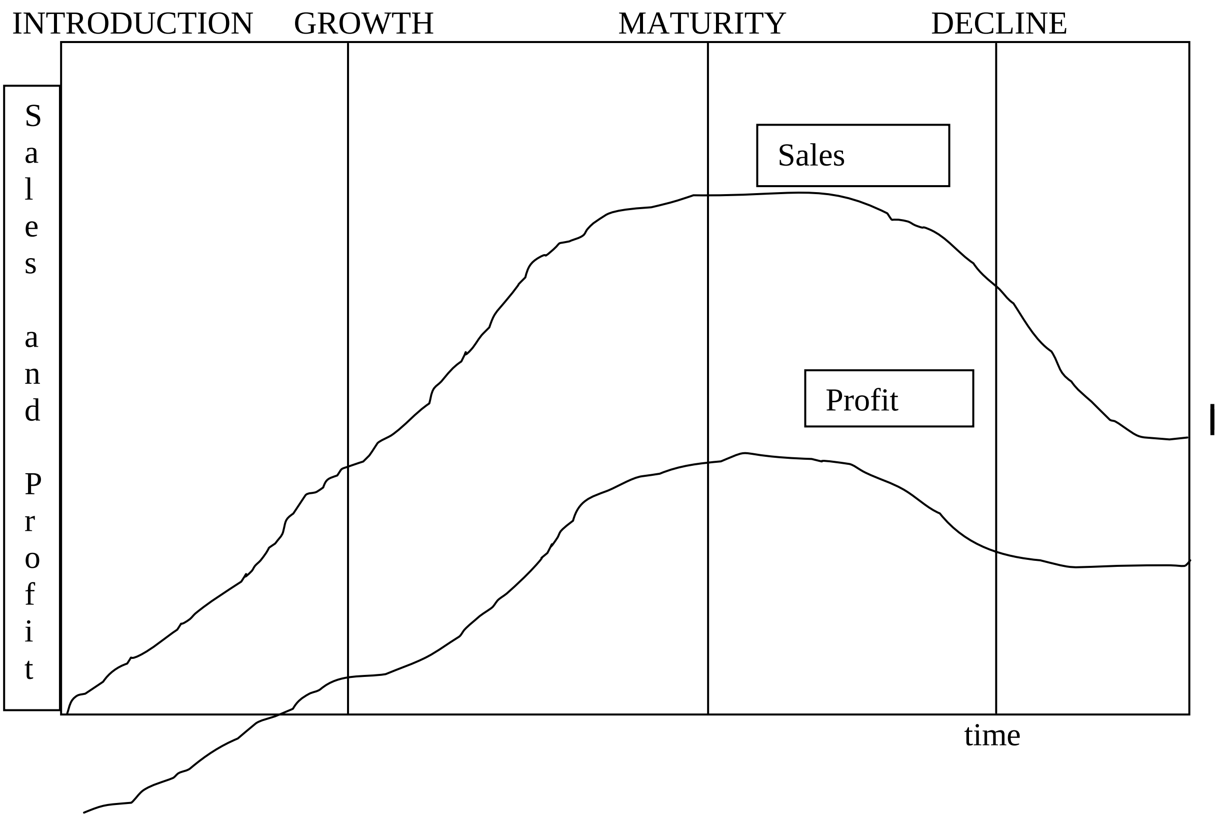
11.5 THE CONCEPT OF PRODUCT LIFE CYCLE

If you observe the profitable life span of products around you, you would often find interesting variations. While some products continue to have long and profitable market existence, others seem to fade away after some time, some very soon after their introduction in the market place. Like living organisms, products also are seen to pass through a life cycle of birth, growth, maturity and decline. What is, however, different is that marketers can often, by carefully planning their product market strategies influence the duration of the growth and majority phases and delay the decline. The stages through which a product passes in its development from introduction in the market to decline and possible discontinuance are referred to as the product life cycle. Figure 11.1 shows the various stages in the product life cycle in terms of the possible sales and profit curve. Let us try to understand the different stages and the way products and markets respond to marketing strategies during these stages

- *Introduction stage:* When you have just introduced the product in the market place relatively a few individuals know about the product, a small number of retailers are willing to carry the product and consequently the sales take time to pick up. If you have managed to understand the consumer requirements well, the sales start showing an upward movement though the rate of growth is slow. This is also the stage when on account of your initial start up costs being high, the profits are almost non-existent or very small. You also need to make a fairly substantial outlay on promotion to create awareness about your product offer, which adds to your introductory costs.



- *Growth stage:* In case the product launched by you is successful, it is said to enter the growth phase which is characterized by a more rapid growth in sales, on account of growing market acceptance. As fixed costs get spread over a larger number of units, the costs per unit go down and your profit position gradually becomes better. From the view of product strategy, this is an important stage because on one hand, your Consumer Franchise is growing and on the other hand, your competitors are also becoming conscious of your presence. They may like to take steps to defend their market position by reducing their prices, or offering products very similar to yours! You need to be prepared to take on the competition by maintaining product quality, attractive prices and providing the consumer a reason to continue to buy from you, on account of the product attributes. This is also the stage, where you may want to add new product variants to counter competitive overtures, and extend the growth potential of your product line.

- *Maturity stage:* As the product becomes more settled in the market, and the competition stabilizes, the sales come to a more stable rate of growth or reach a plateau. The product is in a stage where most of the customers interested in the product have already started using it and the market size is more or less defined, and the demand consists of replacement demand as well as that generated by some new buyers being attracted to the product. Future sales are a function of the population growth and the weaker competitors have exited the market. This is the stage where the entrepreneur prunes his product mix to weed out weaker products and concentrates on the most profitable ones. The maturity stage is usually the longest stage in the product life cycle and is often the most challenging one. You can create opportunities for growth by looking for new markets for your existing products or extend your product line to give a more complete package to your existing customers. Through creative marketing strategies by either market development or product diversification, or even marketing mix modification you can delay the onset of the decline stage.

- *Decline stage:* Sooner or later most products get replaced by new and better products in the consumer preferences and start facing a sales decline. This may happen on account of changing consumer preferences and tastes, improvement in technology or simply by better substitute coming into the market. As noted above the marketers can prevent the onset of decline stage by innovating and preparing themselves to meet these changing tastes and preferences themselves rather than allowing competitors to come out with improved substitutes.

Once sales start declining, it leads to overcapacity and a general inability to meet costs. Unless you can think of strategies to reverse the decline, it is a good move to cut your losses by getting out of a declining market. Some of the strategies used in the declining market include adding new features to the product to give extra benefits to the consumer, improving the incentives to the distribution channels in order to get better support from them, improving product quality or adjusting the price to make the product more suitable to another market segment.

You must however, always bear in mind that the product lifecycle and the duration of the product in different stages of the life cycle is often a result of the product and market strategies used by the entrepreneur rather than a natural progression that every product must follow.

Activity 4

You have only to think of food products which were once popular and are no longer seen in the market, because consumer preferences related to food have changed so drastically. On the basis of the market survey of your local market, try to identify some examples of value added food products which can be said to be in the various stages of the product life cycle. List these examples

Introduction stage…………………………………………………………….

Growth stage………………………………………………………………….

Maturity stage………………………………………………………………...

Decline stage………………………………………………………………….

(**Hint:** Look for some value added food products which have very recently been introduced in the market, some which have been around for some time and some which are now out of consumers favourite brand set-On the basis of what you have studied in this section, try to classify the products in the above stages).

11.6 BRANDING AND PACKAGING DECISIONS

Branding

In order to enable consumers to identify and distinguish between different product offerings, most consumer and industrial products need to have a distinctive name and an identifiable packaging that make them stand apart from other products. An important decision in your product strategy is to have a brand name for your products which is easy to remember and recall when the consumer is planning to buy the products. Let us try to understand the different terms that are used in the context of branding

A **brand** is a word, mark, symbol, or a combination of these used to identify goods or services

A **brand name** is the part of the brand consisting of a word, letter, a group of words or letters comprising a distinctive name which is intended to identify the goods or services of a seller or a group of sellers and to differentiate them from those of competitors. The brand name can be vocalized and therefore, can be used to communicate.

A **brand mark** is that part of the brand which can be recognized but not vocalized.

But **trade mark,** on the other hand, is the part of the brand which enjoys legal protection.

Entrepreneurs prefer to brand their products as branding provides several advantages in marketing. Some of these are

- A well chosen brand name helps invoke some of the desirable features of the product, for example Tang, Dairy Milk, Sunfeast, Shaktibhog etc.

- A brand helps in providing a distinctive image to the product and aids in distinguishing it from competitor's offerings.

- On account of easy identification, the brand helps the middlemen i.e. the wholesalers and the retailers in order booking, inventorying and other distribution functions.

- On account of association of favourable experiences with the brand name, branding makes it easier for consumers to develop brand preferences and ultimately brand loyalty.

- Over a period of time, goodwill of a brand becomes a valuable asset for a producer and is referred to as brand equity

- Brand equity, gives the organization a distinct advantage in future product introductions and market development.

You must therefore, think of a suitable brand name for your value added food products before introducing them in the market place. There are certain costs associated with branding in the sense that you would need to promote the brand name and establish an identity for the product by advertising and creating brand awareness. In view of the advantages already mentioned however, a brand becomes an important tool in the strategy for successful marketing by entrepreneurs.

Selecting a brand name: As the essential function of branding is to help product identification, recognition and recall. There are certain considerations which you must keep in mind when selecting a brand name.

- S*uggestive:* A brand name should suggest something positive about a given attribute of the brand for example the above brand names like Tang and Shaktibhog provide a hint about the product attributes of the drink concentrate being tangy in taste or the flour being an energy providing food.

- *Convenient and memorable:* It should be easy to spell, pronounce and remember (Kissan, Amul).

- *Distinctive:* It should be distinctive enough for people to clearly associate themselves with a given product and should not too closely resemble another brand especially in the same product category.

- *Association value:* The brand name partly on account of its memorability and partly on the basis of its relationship with product attributes, should be able to build up a strong association between the company offerings and the brand. This often happens because while promoting the brand, manufacturers repeatedly use some tag line to focus on the key benefit of the brand; For example the Maggie Brand uses the tag line "Easy to cook, good to eat". Over a period of time, consumers come to associate the value of a time-saving, tasty food product with the brand name Maggie.

Packaging Decisions

Packaging has often been defined as the art, science and technology of producing a container for the product and making it suitable for transportation and sale. A well designed package is an important tool for marketing communication, product differentiation and enhancing the value perception of the product. You have only to look around yourself, to specially in the context of value added food products to appreciate the revolution that has taken place in the area of packaging. The amazing variety of packaging options available today makes it possible for the marketer to use packaging as a strategic advantage in marketing. The choices for value added to products range from the traditional plastic and glass bottles to food grade pet containers, sachets, Tetra packs, aerosol cans and dispensers. The choice available both in terms of material and design is tremendous and it is up to the entrepreneur to select the best possible alternative for gaining the best competitive advantage. While taking packaging decision you must however be conscious of the functions that packaging must perform in order to add value to the product and justify the cost of packaging. The functions that packaging should perform include the following:

1. *Protection:* The most basic function of packaging is protection of the food products from environmental and physical damage to which the product maybe exposed to during transportation, storage and movement from the point of production to the point of consumption and disposal. The various hazards that the product may face during the above stages may include damage due to rough handling, extreme climatic conditions leading to spoilage, contamination, absorption of moisture, loss of fluid and pilferage because of unsafe packing. Your selection of the packaging material and

packaging design must ensure the protection of your product against all these hazards. The cost of packaging must be seriously considered against the cost of possible damage and spoilage during transit and before usage of the product.

2. *Enhancing product appeal:* In the case of food products packaging is being imaginatively used to enhance product appeal. You must understand that in the case of retail situations, the package acts as the silent sales person for the product especially in the self service situations. The package therefore, must *attract attention*, give a *clear idea* of the product; it must *inspire confidence* by looking *clean, hygienic and sturdy*; must be *convenient to handle*, and *to carry and store*

3. *Enabling sales promotion:* Packaging plays an important note in implementing sales promotion schemes as the package can be adapted to give additional benefits to the consumer in several ways For example, Money off package, Premium package, Extra volume for the same price, Benefits given to the consumer for the return of package in the event of a repurchase.

4. *Providing information:* Through labelling, packaging performs the important function of conveying information to the consumer about the product ingredients, prices, shelf life, instructions for use and any special caution that needs to be applied in respect of the product on its storage and usage. In the case of food products, if such information provision is also a legal requirement.

5. *Performance features:* In order to enhance the value for the customer, packages today are also equipped with functional features so that their usage value in the eyes of the consumer goes up. You would have seen ketchup packaged in plastic bottles with dispenser caps, or pickles in spill proof jars or plastic packs with zip lock systems. You may think of innovative ways of adding utility features to your product packaging like creating an aerosol package for salad dressing or a sprinkler cap for masala mixes to provide ease of usage of the product to the consumer. Creative packaging with additional features like these, sometimes results in brand purchase and ultimately brand preference.

Activity 5

A. Try to recall five most popular brand names of value added food products across different product categories. How well these brand names rate on the five qualities of a good brand name suggested above.

Brand 1 (name)……..……………………………………………………...

Brand 2 (name)……………………………………………………………

Brand 3 (name)……………………………………………………………

Brand 4 (name)……………………………………………………………

B. Identify the various functions that packages of value added food products fulfil besides the protection function, by surveying the packages of the value added food products in your local market.

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(**Hint A:** You have just seen the criteria which define a good brand name. In respect of the brands selected by you, evaluate to what extent these qualities are displayed by the brand names.

B: Protection is the most basic function performed by packaging, on the basis of what you have studied in the section above, comment on additional functions that product packaging is seen to perform in the products chosen by you).

11.7 DIFFERENTIATING AND POSITIONING PRODUCTS

As a manufacturer of value added food products, it would be easier for you to decide on the various alternatives of your marketing strategy if from the very beginning you had a clear idea as to how you want your products to be perceived by the target consumers of your products. According to Philip Kotler, the designing of your offering and image to occupy a distinctive place in the minds of your consumers is called **positioning**. In the context of the product category offered by you in the market, you can take conscious, planned action to assign a specific image and meaning to your products for your target market. For example, for your value added food products, you can select a position of completely natural food products with no artificial additives or preservatives, or that of a value for money product, offering good nutritive value at economical rates or one that offers a complete range of possible flavours, or one that comes out with new, exciting and innovative taste combinations. Once you decide on a particular positioning to take, your marketing decisions like product attributes to focus on, packaging, promotion, distribution will need to be taken in consonance with the desired position so as to reinforce the desired image in all aspects of marketing activities.

Positioning is based on how you want to differentiate your product offer from your competitors' products. Product differentiation can be created on several bases some of which, relevant to value added products are discussed below:

Product attributes: As mentioned earlier, you can identify product attributes which you would like to focus upon, through which you are offering a distinctive value to the customer. This could be in the form of a particular taste (Maggie Hot and sweet tomato Ketchup) or the most compete range of flavours being offered in fruit juices or jams, or a low calorie variant on account of non-addition of sugar in your range of fruit juices and preserves. When trying to identify the attributes of which you want differentiate your products, you must consult your potential customers to have an idea of the attributes that are important to them.

Product form: Products can be differentiated on the basis of the form in which they are offered. For example, Masala mixes can be offered as a dry powder or a paste, provided this differentiated form offers a distinct advantage to the consumer in terms of usage or storing convenience.

Product packaging: As noted earlier in the section 11.6 on Packaging, we had discussed how packaging can be used to give a differential advantage to the customer. Reusable packages impart a distinctive value to the consumer, as do other convenience factors like dispenser caps, easy to handle bottles, sachet packs etc.

Product quality: You can consciously take the decision to offer a certain level of product quality and use this basis of differentiation to justify your prices. A quality differentiation must be consistently supported by product performance, otherwise it may prove to be counterproductive.

Pricing differentiation: You can differentiate your product on the basis of most economical prices or on a value for money basis. Alternatively, to convey a high quality image, entrepreneurs sometimes follow a high price strategy (e.g. Mothers recipe strawberry preserve) and aim at the high profile of the market.

Product delivery: It is also possible for small entrepreneurs to get an advantage in the market by offering service advantages like free home delivery especially for large buyers. This may specially work for you if you offer a complete range of value added food products rather than just one or two items.

Activity 6

Survey the market around you and study the leading brands of value added food products. Study their marketing communication as well as packaging. What, according to you are the ways in which these brands have been differentiated from their competitors? Try to identify the basis in each case and justify your answer:

Brand 1……………………………………………………………………..

Brand 2……………………………………………………………………..

Brand 3……………………………………………………………………..

Brand 4……………………………………………………………………..

Brand 5……………………………………………………………………..

(**Hint:** You must study the advertisements of all the five brands selected by you and the information provided on their packages. Study the main focus in each advertisement to understand the basis of differentiation being pursued by each brand).

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What do you understand by the terms product, product mix and product line? Explain by giving suitable examples of value added food products.

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2. What are the ways in which products can be classified? How would you classify the following value added food products?

a) Jams, jellies and marmalade.
b) Premium fruit juice.
c) Fruit pulp to be used for manufacture of fruit based confectionery.

Justify your answer by giving reasons for your classification.

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3. How is the concept of Product life cycle used by entrepreneurs to plan their marketing activities? What are the steps that can be taken to delay the decline stage, in the case of value added food products?

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4. What is the advantage of branding of food products by a small entrepreneur? What are the characteristics of a good brand name? How would you advise an entrepreneur planning to introduce a line of natural fruit juices and seeking the suitable brand name for his products?

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5. What are the key functions that packaging can perform? Explain with the help of suitable examples.

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6. Assume that you are an entrepreneur producing a range of pickles, chutneys and other preserves. On the basis of inputs studied in the Unit, what are the ways in which you can differentiate your products?

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11.8 LET US SUM UP

A product represents the offer that an entrepreneur makes to the market in order to satisfy an existing consumer need and earn a suitable return on his investment. In the context of value added food products, this unit tried to define the concept of a product, the product mix and the related terms. The unit also explained the way products can be classified and the criteria that should be applied, while making the selection of a suitable product to manufacture. The concept of product life cycle was covered to enable you to understand the different stages in the market development of a possible value added food product and therefore equip you to identify suitable strategies for various stages in the Product Life Cycle (PLC).

Branding and packaging are important decisions for an entrepreneur as these would enable him to carve out a distinct identity for his products. Advantages of branding and packaging, as well as key considerations that you should bear in mind, while taking these decisions, have been explained.

In the highly competitive market faced by value added food products, product differentiation plays an important role in helping consumers to understand the different values that are being offered by competitive products. The unit also explains the concept of brand positioning and product differentiation to help you apply these important concepts in the successful marketing of your value added food products.

11.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Refer to section 11.2 Product: Meaning and significance and observe the market for suitable examples.

2. Refer to section 11.2 Product: Meaning and significance.

3. Refer to section 11.5 on product life cycle and specially to the decline stage under the PLC.

4. Refer to section 11.6 and look for the inputs given under the heading of branding and brand name selection.

5. Refer to section 11.6 and look for the inputs provided under the heading of packaging.

6. Refer to section 11.7 and look for inputs provided under the heading of product differentiation.

11.10 SOME USEFUL BOOKS

1. "Entrepreneurship Development for Women" a Manual for Trainers, ILO-Sida If publication, December 1996A.

2. "Principles of Marketing", Philip Kotler and Gary Armstrong, Prentice hall of India, Seventh edition 2005.

3. MS-93 "Management of New and Small Enterprises", Block 4 – Operating the Small Enterprise. SOMS, IGNOU Publication, 2004.

UNIT 12 SETTING THE PRICE

Structure

12.0 OBJECTIVES

After studying this unit, you should be able to:

- explain the various types of costs in an enterprise;
- describe the relationship between cost and price;
- apply the understanding of cost behaviour to price setting;
- define the objective you want to achieve through pricing;
- explain the various methods used by small enterprises for pricing;
- get an understanding of consumers realization to pricing decision; and
- set prices appropriate for your product and market situation.

12.1 INTRODUCTION

As an entrepreneur, pricing is one of the most important decisions you will have to take in respect of your products. You will find that a lot of your decisions become dependent upon the price that you are able to fetch from the market for your value added products. Not only the price set by you should cover your costs, it should also provide you with a reasonable margin as your earning. However, the consumer that you are planning to focus on for your products, must be able and willing to pay the prices that you are planning to set, otherwise the product will not be able to generate the demand that you wish to generate. As you are not the only one offering these products, you will also need to take into consideration what the direct and indirect competitors are charging for similar products. In this unit we will look at the factors that influence the pricing decision, the various cost that you must know, and the possible reactions of consumers to different pricing levels. We would also go through the steps in the price setting process, the various pricing objectives and the inputs you need to have before implementing your pricing decision. These inputs would enable you to take appropriate and ultimately, profitable pricing decisions for your products.

12.2 IMPORTANCE OF THE PRICING DECISION

Pricing is one of the key components of the marketing mix. In order to appreciate the importance of this variable put yourself in the place of a consumer. When you want to buy something, one of the first things you ask for is the price of the product. It often becomes the reason of your deciding to buy or not to buy. Ask yourself the question- why do you decide not to buy if the price does not seem appropriate? The answer is that you do not buy if you think the product in question is not worth the money that is being asked for. The exchange between the buyer and the seller is directly dependent upon the valuation the buyer puts on the product. If his valuation, i.e. his own perception of what the product should be worth, does not match the price that the seller has put on the product, and the exchange will not take place. Pricing as a decision is therefore important because

- It allows the consumer to assess the monetary value that he would need to pay to acquire the product.
- Prices strongly affect the consumer's valuation of the quality of products.
- It is the only source of revenue you would be earning. Your price level becomes the determinant of what revenue will you be able to generate, provided there is demand for your product.
- Pricing decision infringes upon your other decisions in the marketing mix. The price level contemplated by you defines the margin you will be able to make over your costs. Thus margin determines what are the kind of distribution costs you will be able to pay to your distributors and the type of resources you will be able to employ for your product promotion.
- Conversely, you will find that price is also a strong determinant of demand levels. The basic law of demand tells us that the quantity purchased of a given product increases if the price of the same is lowered and vice versa. While it is not true of necessity goods, pries do affect the number of people who will be able to afford the product and therefore is a factor in defining what is the size of the market at a given level of price.
- Your prices also strongly affect the positioning you aim at in the market. The price points enable the comparison of the value offered by you with the value offered by your direct and indirect competitors and allow the consumer to assign a positioning to your product vis-à-vis your competition.

A small entrepreneur is therefore very conscious of the extreme care that he would need to exercise to be able to set the right price for his product, in this case the value added food product that he has chosen for himself. Let us now try to understand the basic foundations of the pricing decision.

12.3 UNDERSTANDING THE BASIC ELEMENTS OF PRICING

At the basic level, you must clearly understand that price determination depends on three fundamentals. These are consumer value, costs and competition. Let us discuss each fundamental element in brief and understand their interplay in the pricing decision.

Costs represent the money value of everything that you will have to spend or utilize in order to create and offer your product for market. You need to be sure, in the short run as well as in the long run that your cost would need to be covered for you to survive in the market. You therefore, cannot afford to price your product below the cost at which you have produced it because you will be incurring losses instead of earning profits. For example, if it costs you Rs. 20,000 to produce 1000 bottles of fruit jam, another Rs. 2000 to package them and Rs. 500 to transport them to the nearby markets, you cannot afford to price one bottle below Rs. 22.50 because then each bottle sold would result in losses. Costs thus represent the floor below which you should not go in taking your pricing decision.

The consumers capacity and willingness to pay a given price is another variable that you will have to consider. In a given market, what is the value that consumers assign to a product like a bottle of fruit jam? How many of them, are willing to buy a bottle of jam, without the guarantee of a known brand name, at a price of, let us say Rs. 35 per bottle ? You will have to make this assessment, because in a given market the number of people, who are able and willing to buy at the price being thought of by you, will determine the demand that exists at that price level. You would need to assess what is the level of price at which the consumers in your chosen market segment are willing to buy your product, simply because above that level you will not be able to find any takers for your bottle of jam. The consumers ability to pay for a product in a given market thus defines the ceiling above which you cannot afford to charge, because a very limited market would result at that level.

It must now be clear to you that there are two limits, lower limit and upper limit that you must consider in your pricing decision, Costs on the one side form the lower limit and the customers ability to pay on the other side, constitutes the upper limit beyond which you should not go warns you while taking the pricing decision. You may have the freedom of charging what you want between these two levels, if you are the only one in that market producing fruit jam. Unfortunately, this is seldom the case because all kinds of value added products like jams, jellies, fruit juices and pickles and the other range of such products, are there always produced by other producers who are your competitors. All the producers who are in the market offering the same product that you are producing or are planning to produce are your competitors. As their prices are also commonly known to your prospective customers, you do not have the freedom of charging prices that are too different from those being charged by your competitors. The third dimension that you would have to study before you set your prices is the dimension of your competitors. To summarise the three basic elements you would need to define the following:

- Who are my customers and what is the value they put on a product like mine? In other words, what is the price at which they will be willing to buy?
- What are my total costs in producing, distributing and promoting my product?
- How do my competitors price the same or similar products?

Activity 1

Talk to about 5 people who are the likely consumers of the value added products and ascertain the possible prices they may like to pay for the following:

A. A bottle of mixed pickle 9250 gms)
B. Tomato (200 gms)
C. Fruit squash (500 ml)

How do these prices compare with the market prices of these products? Comment upon the gap if any.

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12.4 WHAT SHOULD YOU KNOW ABOUT COSTS?

There is a common and widespread belief that costs determine prices. This is on account of the fact that costs are one of the important elements of the pricing decision as you saw in the previous section. You also saw that factors like demand and competition are the other two important factors that help you in finalizing your price. So, while costs continue to be important, their importance cannot be exaggerated you must clearly understand that if your costs are working out to be of a certain level, and covering them results in a price at which there is little or no demand, then you will have to seriously reason out costing and find out ways of minimizing costs in order to survive in the market. In order to clearly understand your costs, let us try to find out the various types of costs and see how they can be combined to give the total cost.

Costing is the way you calculate how much each individual product produced by you will cost you to produce and deliver. In order to realistically price your product, you need to cost the product first because then you will be able to

1. know what is it that you must recover and assess what margin you need to set to earn a reasonable profit;
2. set prices for each product; and
3. match your product offer with the expectation of your chosen set of target customers.

You will find that there are major differences in costs between one producer and another. They may be due to the way they source their raw materials, or utilise their resources or the way they use manpower and utilities like electricity and water. They will also have different cost structures if they have different skill levels and use different grades of raw materials, or different types of packaging. Let us list out the types of costs that may be incurred in the production of value added products.

1. **Direct Costs:** These costs are directly related to the manufacturing activity of the product under consideration and include :

   a) *Direct material cost* **-** Actual costs of raw materials that go into the finished product.

   b) *Direct labour costs* **-** Cost of the labour or manpower that is used to produce the product. Even if you are using the members of your own family, you must assign labour costs. These would be equal to what they would have earned as workers elsewhere if they had not been engaged in the home production activity.

   c) *Other direct costs* **–** Costs of the facilities like fuel, and rent of machines if any, packaging material, transport, storage expenses or tools and equipment etc.

2. **Indirect Costs:** These are the costs that cannot be directly linked to the manufacturing of the product but are required to make production possible. You must also remember that these costs will continue to be incurred whether the production of your value added products is going on or not. These costs include:

- The rent of the building, maintenance of the building, equipment machines etc.
- Power and electricity, water, and other municipal costs like taxes.
- Costs of interest on loans that you may have taken.
- Salaries of people engaged by you who are not directly involved in the production e.g. helper, delivery boy or some consultation fees that you may have paid for general administration or production/marketing of your value added products.
- Stationery postage and telephone if any.
- Costs incurred in providing your product.

You may also look at costs in another way to identify them as fixed and variable costs. All costs that you incur can be classified either as fixed or as variable costs.

Fixed Costs: Costs are those that do not change with the quantity of products produced, i.e. these are costs that cannot be avoided even if no production is being undertaken on a particular day or in a given period. These costs include rent of the building, salaries given to people involved in the production activity, interest on loans, monthly charges of electricity power and water etc.

Variable Costs: on the other hand variable costs are those that vary with the level of output. They directly depend upon the quantity of products being produced. They include the raw material costs, machine operating costs, direct labour costs, packaging, transportation of finished goods etc. You would appreciate that variable costs would arise only when production is going on. On a given day when there is no production activity, the variable costs would be zero.

In order to be able to calculate the total cost per unit of your product, for which the pricing decision is to be taken, you should know the following:

1. Total fixed costs of your organisation
2. Total variable costs for the manufacturing of that product
3. Period over which the fixed costs are being incurred

   ❖ Cost for each product = Total fixed costs + Variable costs of the product

The factors which cause your total costs to rise and make you uncompetitive include the following:

- Your lack of knowledge or uncertainty about the needs of your customers regarding the value added products.
- Inadequate knowledge about the sources of raw materials and availability of others resources.
- Your inability to purchase raw materials in large quantities.
- Uncertainty about the quantity to be produced each day or per period.
- Lack of basic skills relating to introduction or selling of value added products
- Inadequate knowledge about the low cost alternatives for raw materials/ equipments/workers.
- Lack of appropriate standardisation in the production processes, packaging and distribution.
- Inadequate training of labour and other production related staff.

Activity 2: Working out the total cost of the product

Take the following table as an illustration of the various costs associated with the product of a given value added product like jam or fruit preserve. Using the information given above, work out the total cost of the product.

Item/material required	Quantity	Cost/rate per unit	Quantity required per unit	Cost/unit
Unit	30 kg	Rs. 25 per kg	2 kg	Rs. 50
Additive				Rs. 5
Sugar	15 kg	Rs. 8 kg	500 gms	Rs. 4
Packaging		Rs. 2/bottle		Rs. 2
				Rs. 61

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In addition there are 2 workers involved per day who produce 300 kg of preserve per month. Their salaries are Rs. 1500/month each. Cost of labour per unit i.e. per kg production is Rs.10.

The direct cost of production = Rs. 71 (=Rs. 61 + Rs. 10 = Rs. 71)
What is the price that you would like to set?

Hint: To the above you will be required to add all the indirect costs divided by the total number of units produced per month, to get the indirect cost per unit. Suppose these costs are Rs. 5/-.

Your total cost of production so therefore = Rs. 71 + Rs. 5 = Rs. 76.

∴ Total direct cost per unit + Total indirect cost/unit = Rs. 76.

Once the goods are produced, you have to incur distribution costs to let the goods reach the hands of the consumer. If you want to sell through dealers i.e. wholesalers and retailers, you will have to incur the cost called distribution margin. If you want to sell directly, you still have to incur delivery costs but these will be in the form of transportation, warehousing and keeping the inventory of the finished goods. Assume, for the sake of simplicity that these selling costs are equal to Rs. 4/ unit. Your total cost of the product is therefore Rs. 80 (Rs. 76 + Rs. 4) = (Cost of production) + (Cost of delivery).

In order to determine your price, you will have to decide the margin you would like to charge to get a reasonable profit margin. The total price per unit, to be charged is given by the simple formula

Price = Total cost/Unit + Markup margin per product

Suppose you decide to earn a 15% margin on your total cost. This works out to Rs. 12. The final price that you would need to charge would be equal to Rs. 92 per kg. In case you want to sell in500 gm bottles, the price should be around Rs. 46.

Activity 3

Based on your information of the market price of raw materials and an assessment of labour costs involved, try to work out the possible margins being charged by 2 branded value added products of your choice.

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We have in the above example used the direct cost, indirect cost classification to work out the total cost and estimate the final price.

You may also use the classification of fixed and variable costs for the same exercise for calculating the total cost.

In order to work out the total cost, you would need the following information.

1. Fixed cost of the Production Unit

   a) Cost of total machines & equipment
   b) Cost of rental of the building
   c) Cost of furniture and fixtures
   d) Cost of installation transport etc.

2. Monthly payments of the unit

   a) Payment of electricity/water/telephone
   b) Salaries of the workers if any
   c) Salary of self
   d) Office costs if any
   e) Cost of production

3. Variable cost of raw materials and labour used.

Using the above information, work out the total cost/unit of any value added product of your choice.

12.5 WHAT SHOULD YOU KNOW ABOUT YOUR CUSTOMERS?

The basic objective of the pricing decision is to set it at a level where exchanges will take place i.e. the price at which a large number of consumers will be willing to buy.

You must also appreciate that in a country like ours, your potential consumers can also be your competitors in the sense that they can produce most of the value added products you intend to offer, by themselves. While evaluating pricing options, you must keep in mind that if the prices are too high, consumers may simply not consider the products worth the money.

From the point of view of the consumer, prices become barriers to purchase in both circumstances, when they are too low or too high. Above a particular price, the product is perceived as being too expensive and below a particular price, it is perceived as being of too low a quality to be considered desirable. Looking at the consumer group you wish to cater to, you must get an appropriate idea of these two limits. These limits constitute the range above which or below which you should not set your price. It is a good idea to get an assessment of the prices that consumer will be willing to pay for your type of value added product through discussion with consumers or a survey of the prevailing market prices for similar products,

Another assessment that you would need is the price elasticity of demand. This price elasticity of demand is a measure of what is the responsiveness of consumer to small changes in price. Is the product of that type where the price consciousness of the consumer is very high and any small change in price by other producers, will shift the demand in favour of the competing product? You can protect your product from direct price competition by differentiating it on the basis of quality, freshness, taste, flavour, low sugar content or any other value that you may choose to include. To summarise, the different factors that you would need to know about your consumers include:

- What are the prices that your consumers are willing to pay for your product?
- What is the approximate demand that is likely to result at different price points?
- How sensitive are consumers to changes in prices for your type of product?
- What are the factors other than price, that consumers assign value to when they select value added production?

Activity 4

For a product like pickles, find out from different sections of your prospective consumers the prices they are willing to pay for a 500 gm bottle of good quality pickle. Based on the assessment of costs as in activity 1, what type of margins will these prices enable you to get ?

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12.6 WHAT SHOULD YOU KNOW ABOUT YOUR COMPETITORS AND TRADE PRACTICES?

At any given point of time, wherever you contemplate putting a value added product on offer, you must be aware that there are several competitive products already on the market. People who fulfil the same need of consumers, that you are trying to fulfil through your product, are your competitors. As noted in the earlier section, value added products represent a category where the consumer himself may also be a competitor.

While pricing your product, you need to be aware of the prices that your competitors are charging. A casual survey of the retail market would give you a clear idea of the final price that the existing consumers are paying for your competitors' product. In order to give them a reason to buy, you need to either price the product a little below that of the competitor while keeping similar levels of quality, or include some other value in the product for which the consumers are willing to switch their brands at the same price or even slightly higher prices. You must clearly understand that the competitors' prices create what is called a reference point for the consumers against which they assess all new offers. You, therefore, cannot afford to have prices that are radically different or unsupported by a reasonable value proposition.

In the next unit, you will study in detail about the distribution practices that emerge to bridge the gap between points of production and points of consumption. It is, however, relevant here for you to understand that distribution costs also have to be absorbed in the final price of the product. When you develop value added products, in order to take them to the point where consumers can access them, you will need to use the services of middlemen like wholesalers and retailers. These distribution agencies operate on the bases of margins that they earn on the products they help to sell. In common parlance, the terms on which you share the distribution of your products to the markets selected are known as terms of trade. These include the quantum of margins (in terms of percentage) payable to the distributors, the types of services performed in return, the type of warehousing and promotional support provided and the terms of payment i.e. cash or credit, terms of credit etc.

As distributors are independent businessmen in their own right and provide the essential services of creating access for the customers to your products, for a new manufacturer there is seldom any choice but to follow and abide by the existing terms of trade. You should, while taking the pricing decision, be aware of what are the costs generated by the different types of channels of distribution you can select. These costs will also become a factor in the total costs that would need to be recovered through your pricing decision.

12.7 UNDERSTANDING PRICING OBJECTIVES

For your enterprises, you may have several objectives at a given point of time. Your pricing goals would reflect what you want to achieve as an entrepreneur. For example, a new entrepreneur in a highly competitive environment has the primary objective of survival and therefore, his pricing objectives would reflect the need to be able to merely survive in the market place for the time being. The various pricing objectives that entrepreneurs seek include:

- Survival
- Maximising current profit
- Maximising market share
- Market entry objectives
- Product quality leadership

Survival as an objective is followed if the enterprise is faced with more capacity than the demand, intense competition and changing preferences of the buyers. The prices are set at a level which will enable the entrepreneur to stay in the market as long as possible. The entrepreneur, in such conditions fixes the price at a level which covers his variable and fixed cost and he tries to stay in business. This is a very short term objective and soon the entrepreneur will have to decide how to add value to his offer or be prepared to exist in the market.

Another short term objective that many small entrepreneurs follow is that of maximising current profits. When you understand that there are different demand levels that will result at different prices, and you are interested in whatever maximum you can get from the market, you would select a price level that produces, for a given demand level, the highest current profit for you. You must however, know that under this objective the entrepreneur may be ignoring the long term objectives of his organisation.

Some entrepreneurs, specially those who have attained a certain size of business are interested in increasing their share of the market because they believe that a larger customer base will allow them to cut their costs and in the long run allow them to have higher profit. Their pricing objective is to maximise market share, and they will select the lowest possible price, if the market is price sensitive. You are all familiar with the example of Nirma washing powder. Indian consumers of detergent are very price sensitive. At the time when established detergents like surf and sunlight were being sold for Rs. 30-35 per kg. Nirma was introduced at a price of Rs. 6 per kg. It continued with similar price levels for quite some time because the objective was to take a large share of the market.

This strategy is also termed as particular pricing because this enables you to penetrate the market, in a competitive but price sensitive situation sometimes, where the entrepreneur is able to create a unique or an innovative product which is new to the market and therefore has a great novelty value, he is in a position to charge extra for the novelty value of the product. The pricing objective that is selected in such circumstances is called market skimming. The product is initially priced very high, so that the customers with higher paying capabilities and with current desire for the product will be attached and will give initial high profits to the entrepreneur. As the novelty wears off and the product gets more well established, the prices are reduced to a level where the larger population can afford to pay. The sales margin will go down but the higher volume will still allow the entrepreneur to make profits.

Sometimes, entrepreneurs may wish to present their products as the highest quality products and charge high prices. In this case, he is conscious that his prices limit the total size of his market, but pursues that objective in the hope that his product quality leadership will be established and in the long run it will be able to create a reputation for high quality.

As an entrepreneur, you need to select an appropriate pricing objective based on what are the overall business objectives you are seeking at a given point of time.

Activity 5

From among the above pricing objectives, what are the objectives you would like to select for yourself?

a) At the introduction stage
b) At the business growth stage

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12.8 ALTERNATIVE PRICING POLICIES THAT ENTREPRENEURS FOLLOW – RELATIONSHIP BETEWEEN PRICE AND QUALITY

Variable Price Policy

Under this policy, different price are charged for different customers depending on the situation prevailing in the market. Some situations under which variable price policy is adopted are:

1. Difference in the size of the customers (e.g. bulk customers may be offered lower price);
2. Difference in the anticipated business from different customers;
3. Difference in the bargaining power of the customers;
4. Difference in the demand and supply position at various locations;
5. Difference in the customers' ability to pay; and
6. Ignorance of the customers.

Some entrepreneurs adopt variable price policy in their effort to maximise profits. They determine the minimum price to be charged by the total cost of the product, and the maximum price by the customers' ability to pay. Bargaining is usually resorted to in finalizing a deal. As such, this policy may be detrimental to the long-term interest of a firm.

Base Price and Discounts Policy

Under this policy, a base price or least price is used and varying price discounts are offered to different categories of customers. Under the variable price policy, the price is charged according to the particular situation. However, under the base price and discounts policy, discounts are offered uniformly to all customers and each one of them can avail these on satisfying the stipulated conditions. Discounts are of several kinds: **Trade discount** is given to a trader to cover his costs and provide him with a margin as incentive to deal in the product. **Quantity discount** is offered to bulk purchasers because of their value to the seller. **Cash discount** is given to the customer making cash down or immediate payment. **Seasonal discount** is given to boost the sale of a product during slack season. Electric fans, woollen garments, and cooler pumps are typical examples where seasonal discounts are offered.

Market Rate Policy

Prevailing market rate, many times is the basis on which an entrepreneur determines the price of his product. If the nature of the product is such that it is largely indistinguishable from those of the competitors, or if it is found that all manufacturers are charging more or less the same price for their products, the market rate policy of pricing is usually adopted. In case the entrepreneur finds that the prevailing market rate is not economical for him, he has to lower down his costs somehow rather than increasing the price unilaterally. This method is commonly used in the case of unbranded products like oils and chemicals, and services like courier, tailoring and car or scooter servicing. One advantage of this policy, especially for new small enterprises, is that they get some immunity from the vagaries of price wars.

Market Skimming Pricing Policy

Under market skimming pricing strategy, a very high price is charged in the beginning with the objective of recovering the investment in a short period. High price is usually supported by heavy product promotion. This strategy is seldom possible except when the product is an innovative one and is expected to command good reception from the customers. One cannot continue with such a strategy for a long period of time as high price acts as an incentive to the competitors to enter the field. The price is permitted to fall as the competition sets in.

Market Penetration Pricing Policy

Market penetration pricing strategy calls for a very low initial price in order to penetrate into the market. The strategy puts emphasis on creating a mass market for the product at low margins. This strategy can be adopted when the demand is expected to be price elastic, i.e. customers are price sensitive, and when the economies of large scale production are substantial.

12.9 PUTTING PRICING IN PRACTICE – WHAT SHOULD YOU KNOW BEFORE IMPLEMENTING THE PRICING DECISION

When you decide upon a particular price, there are important aspects of buying behaviour that you should be aware of before implementing the price decision.

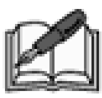
- For the consumer prices are a quantitative value, while quality, branding and promotion are qualitative and difficult to assess. Your price point becomes a reference point for them to make assessment about the product.

- As said earlier, price must be viewed by your target group as being affordable, in the consumers below it should offer good value for money.

- However, if the price is too low in comparison to similar products, the consumers may tend to think that it is of inferior quality. You must carefully assess, that for food products consumers may not like to compromise on essential quality, so even if you are offering reasonable quality, too low a price may give a low grade quality usage to your product and will turn away consumers who are quality conscious.

- Packaging and labelling add to the cost and therefore, result in higher prices. Some entrepreneurs may try to economise economies on these costs but please remember, inferior packaging may allow you to set lower prices but will also interfere with the quality of the product as and when the product reaches the consumer.

12.10 LET US SUM UP



Pricing constitutes one of the most important decisions of the entrepreneur. It often affects the growth and survival of the enterprise. In this unit, you have been given inputs on factors which influence the pricing decision, pricing objectives and the importance of costs consumers and competition in the pricing decision.

Entrepreneurs may like to pursue different objectives at a given point of time and consequently follow different pricing polices. The unit discusses different pricing polices that small entrepreneur may implement, in view of their objectives.

The unit also introduces you to possible buyer reactions to price related decisions and may help you in taking the same into action while you set your prices.

12.11 SELF ASSESSMENT QUESTIONS

1. Why are pricing decisions so crucial for the entrepreneur in marketing value added products?

2. What are the different types of costs you will incur while making

   a) Jams
   b) Pickles
   c) Fruit juice concentrate

   Explain how their costs will affect your pricing decision.

3. Carry out a survey of the prices of the value added products being considered by you for production. What are the different prices ranges that are offered by your competitors?

12.12 SOME USEFUL BOOKS

1. Course Material on MS-93: Management of New and Small Enterprises, SOMS, IGNOU.

2. Satish Taneja and S.L. Gupta, Entrepreneur Development: New Venture Creation, by Galgotia Publishing Company, New Delhi.

UNIT 13 DEVELOPING AND MANAGING DISTRIBUTION

Structure

13.0 OBJECTIVES

After studying this unit, you should be able to:

- explain the importance of distribution decisions for the marketing of value added food products;
- identify the various options available for distribution of value added food products;
- make appropriate selection from among the distribution choices available to you;
- evaluate the advantages and disadvantages of selling through retailers and wholesalers;
- assess the margins that you need to pay to your distributors and measure the impact of distribution margins for the pricing of your value added products;
- demonstrate an understanding of the processes involved in the distribution of goods; and
- evaluate the performance of the channel members used by you.

13.1 INTRODUCTION

As a manufacturer of value added food products, you need to make your products available to the customers who can then decide to buy and consume them. In the previous unit, you have gone through the processes through which manufacturers promote their goods and create demand for their products. In order to be able to consume the products, the consumers require the product to be made accessible at places near them. As the consumers of your products are scattered in large geographical areas it may not be possible for them to approach you directly. Similarly, it may be difficult for you to reach the individual consumers on a direct basis. The decisions that you need to take in order to make your products available for consumption to the final customer are referred to as distribution decisions and form the fourth "P" of the marketing mix for products and services. We will explore the various options that you may like to consider in order to make your value added food products available to the final customers of your products. This unit enables you to identify and select between channel options, evaluate whether direct or indirect distribution is a viable option for you and explore the various tasks that are required to be undertaken to enable the physical transfer of goods from the point of production to the point of consumption.

13.2 DIRECT OR INDIRECT DISTRIBUTION

As a manufacturer of value added food products, you are aware that the conversion of these products into revenue for you would not take place unless customers buy these products and continue to do so. For them to be able to do so, it is important that the Products are made accessible to them at places that are convenient to them. Consumption does not take place unless the goods are available at the right place, at the right time, in the right quantity and at an appropriate price. The term distribution refers to the process of moving the products from the point of production to the point of consumption so that the products become accessible to the people who may like to consume them. When a manufacturer establishes direct linkages with his consumers and sells directly to them without using any intermediaries, this option is called direct distribution. This option is usually possible when the customers are few in number and an individual customer is large enough to give you sufficient sales volume, as in the case of organizational customers. As a producer of value added food products, for example, if you are able to secure large orders from restaurants, canteens or hotels; you can easily supply the products directly to these customers as this will enable you to economize on your distribution margins and establish a direct rapport with your clients. Direct distribution as an option offers several advantages. Direct distribution would involve using your own sales force and arranging the delivery of goods through your own resources. Alternatively, direct selling can also be done by obtaining your orders through direct mail or telephone.

- It allows you to save on distribution margins of commission which are required to be paid to the intermediaries like retailers and wholesalers.
- This saving can be often utilized to offer very competitive prices to your customers; The low selling price can give you a competitive advantage vis-à-vis your competitors
- Your direct contact with your important clients can enable you to customize your value added food products in accordance with the needs, tastes and requirements of the customers.
- You can have a greater control on the final price and the terms of sale offered to your customers.

There are, however, certain disadvantages of using direct distribution. Your initial investment in creating facilities for storage, warehousing, transportation and handling of material becomes substantial. When you use direct distribution as an option your working capital requirements on account of salaries to the sales force as well as delivery related expenditures are higher. The geographical area that you can cover on your own is often limited and therefore, your market becomes limited to local markets or a few large organizational customers. In such cases, your dependence on a single or over a few organizations is so high that discontinuance of orders from any one of them could seriously affect the profitability of the business.

On the other hand, if your customers are individual household consumers, the economics of direct distribution does not work out. Individual consumers may be scattered geographically, and the individual order size per household will be small . In such cases it is difficult, if not impossible for you to reach all your customers on your own. To reach a large number of individual customers, producers use intermediaries like wholesalers and retailers. These intermediaries are independent organizations that enable you to reach your final customers by providing distribution related services to you for an agreed trade margin. When you use intermediaries to reach your final customers, the mode of distribution is called indirect distribution. The advantages of using indirect distribution include the following:

- Low initial investment in distribution facilities.
- Relatively lower working capital requirement in relation to the distribution function.
- Large coverage and access provided to a far larger number of customers.
- Benefits of specialization accruing from the intermediaries.

Your choice of direct vs. indirect distribution is determined by the composition of your customers. As mentioned above, if your customer base is composed of organizational customers direct distribution is a better option. Indirect distribution is a more viable option when your customer base is composed of individual households. These are choices that you need to make at the beginning of setting up of your business and selecting your target customers. You may like to work with a few organizational customers or may like to address the needs of individual households. This decision in turn will determine your choice of direct or indirect distribution.

Activity 1

Make a survey of about ten retail shops in your neighbourhood to collect information on the type of value added food products carried by them. List these products. Try to identify products that do not come from large multinational or national providers. Your list will tell you that quite a few small entrepreneurs today use the indirect channel of distribution for their value added products. Discuss with the retailers to find out the type of retail margins that have been paid for these value added products by the small and medium entrepreneurs.

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13.3 TYPES OF INTERMEDIARIES

The set of organizations, outside your own firm, selected by you to enable your final customers to access your products is known as channel of distribution. A channel of distribution essentially enables the movement of products from the point of production to the point of consumption as well as the transfer of title from the manufacturer to the ultimate consumer. Looking at the market and the type of organizations engaged in the distribution of products, you would find that there are a wide variety of such organizations performing different kinds of distribution related functions, with varying terms of trade. Let us look at different types of intermediaries that if you may need to consider in order to to form your own channel of distribution.

Broadly, all intermediaries can be divided into two categories: Agent middlemen and Merchant middlemen. The agent middlemen are brokers and commission agents who negotiate purchase and sale of goods on behalf of other parties for a certain percentage of commission. Because agent middlemen work on behalf of other parties they do not take title to goods. Quite a few new entrepreneurs find it useful to appoint agents when they first get into the business of producing value added food products to help them find appropriate clients and avenues of selling their products. If you are starting with a small operation and your production is not too large, agent middleman may not find it profitable to act on your behalf.

Merchant middlemen, on the other hand, are those intermediaries who buy the goods from the producers and then sell them on their own behalf. In other words, they take title and possession of goods in order to resell them further. The merchant middlemen can be of several types viz. wholesalers, retailers, cooperatives and supermarkets, multiple shops or chain stores and department stores. In order to establish your channel of distribution, you will need to decide a specific combination of these intermediaries. Let us look at the main functions performed by these intermediaries so that you can accordingly take your channel decision.

Wholesalers: The term wholesalers includes all establishments and businesses engaged in purchase of goods from the producers for the purpose of reselling them to retailers or industrial, commercial, institutional or professional users or to other wholesalers. The principal business of wholesalers is buying goods in bulk and reselling them for a profit to (a) retailers who then resell the goods to the final customers or (b) utilize the goods in the course of operating an enterprise or business. In performing the distribution related activities, the wholesalers perform the following functions:

a) Taking possession of goods, maintaining storage facilities and maintaining adequate stocks in terms of both variety and quantity on a regular basis.

b) Delivering goods to customers (You must appreciate that the customers of wholesalers are retailers, industrial or professional enterprises and other, smaller wholesalers).

c) Taking ownership or title of goods from the producer and passing it on to the customer when the sale is made.

d) Participating in promotional activities for trade promotion initiated by the producer.

e) Negotiating on prices, terms of trade and terms of sale with both the producer and the customer.

f) *Taking risks:* Risk taking is a major function performed by the wholesalers. By taking the ownership of the goods, they assume the risk of obsolescence, pilferage and damage to the goods as the goods are now owned by them. In the case of new untried products or unknown products they also take the risk of being left with stocks of unsold goods, if the goods are not accepted in the market.

g) *Ordering:* The flow of ordering moves from the final consumers via retailers and wholesalers to the manufacturers. Wholesalers, order the supplies of goods from various manufacturers in anticipation of the order flow from the retailers and final customers.

h) *Financing:* Wholesalers, by selling the goods on credit to the retailers and collecting the payment after an agreed time period, provide a vital financing support to the retailers.

Retailers: The term retailer includes all establishments and businesses engaged in selling goods for personal or household consumption. The distinction between the wholesalers and retailers is that the retailers sell primarily for ultimate use by the final consumer. You will find a variety of retail establishments existing in our country, ranging from consumer stores, multipurpose retail stores to sophisticated departmental stores. In terms of distribution activities, retailers perform the following functions:

a) Taking possession of goods from wholesalers, maintaining storage and desired stocks in order to fulfil the requirements of the final consumer.

b) Passing the delivery of the goods to the final consumer for price.

c) Taking ownership from the wholesaler to retailer and passing it on to the final consumer.

d) Participating in the promotion programmes of the manufacturer by organizing store displays and acting as final deliverers of sales promotion schemes directed at the final consumers.

e) *Risk taking:* Like wholesalers, retailers also take the risk associated with ownership. Their risk in the case of unsold merchandise may be partially offset if the wholesaler or manufacturer agrees to accept the returned unsold stocks.

f) *Information flow:* As they are in touch with the final consumer, retailers are a source of valuable information about the consumers' tastes and preferences, buying habits and paying capacities. Retailers participate in information flows backwards to the manufacturer so as to improve services to the final customer.

You would by now have noticed that the functions performed by the wholesalers and retailers are quite similar except for the fact that the scale of operations by wholesalers is much larger as they buy and sell in bulk for the purpose of reselling. The retailers, on the other hand, sell for the purpose of consumption by the final consumer. Their distribution related activities are directed mainly towards the ultimate consumer. There can be several types of retail establishments as we have noted earlier, some of the common ones being departmental stores, cooperative stores and chain stores.

Departmental stores usually located at a central location, provide a great shopping convenience to the modern customer who is short of time, by providing them a range of products under one roof. Being able to attract a large number of customers they are able to manage a large turnover even though their margins maybe small. Their large size enables them to buy directly from the manufacturers and avail bulk discounts thereby saving the wholesalers' margins and passing the benefit on to the consumer in the form of lower prices. As a producer of value added products, you may consider departmental stores as an option because your products can get a large exposure to your target customers in such locations.

Cooperative stores or consumer cooperatives are run by societies formed by consumers themselves. The basic purpose of the cooperative store is to eliminate the middlemen and obtain the goods for their members at a low price. Like departmental stores, cooperative stores also obtain their supplies in bulk and enable the consumers to get the benefit of low selling prices. Some of the common examples of consumer cooperative stores are super bazaar and the Central Government Employees' Consumer Cooperatives.

Chain stores or multiple shop systems represent a concept where a number of stores are managed by one common ownership and management. The various stores can be located in different cities or at different locations in one large city. The chain stores usually deal in similar types of goods for example the Bata Shop, and the Phillips appliances shop. Food based chain stores are becoming very common in metropolitan cities, named as food bazaars or food courts. They have become a good outlet for the introduction of new food products and availing a larger variety of food products in one location. Such food bazaars may be a good outlet for the value added food products for you to consider.

Haats and weekly markets: Rural consumers, on account of the absence of organized markets in the villages, carry out a lot of their buying activity at haats and weekly markets held around their villages. As the purchasing power of the rural customers has grown, marketers have found that these weekly markets provide a lot of access to a large number of customers in the non-urban markets. You must realize that the rural market in India is a large one, with high potential for development. Though the market for value added food products may at present be very limited, the potential for developing this market cannot be ignored.

Activity 2

Make a visit to the following types of retail outlets in your locality:

A. A super bazaar or cooperative store.
B. A departmental store.
C. A general provision store in your own colony.
D. A weekly market organized near your colony.

Make a list of the type of value added food products you find at these retail establishments. How do you think your own proposed value added food products will fit into the product assortment being offered by these stores? Which type of retail outlets will be most suitable for your value added food product and why?

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13.4 IMPLICATIONS OF USING INTERMEDIARIES: CHANNEL LEVELS

By selecting an appropriate channel, you as a producer of value added products are trying to bridge the gap between you and your final consumers. Now that you have looked at different types of intermediaries operating in the market place, you can decide in terms of the levels or the number of channel intermediaries you want to mobilize to reach the final customers. Your choice would be strongly dependent on the market coverage you want and the scale at which you want to operate. Since you are a producer of consumer goods, the following channel options are available to you as diagrammatically shown in the figure below:

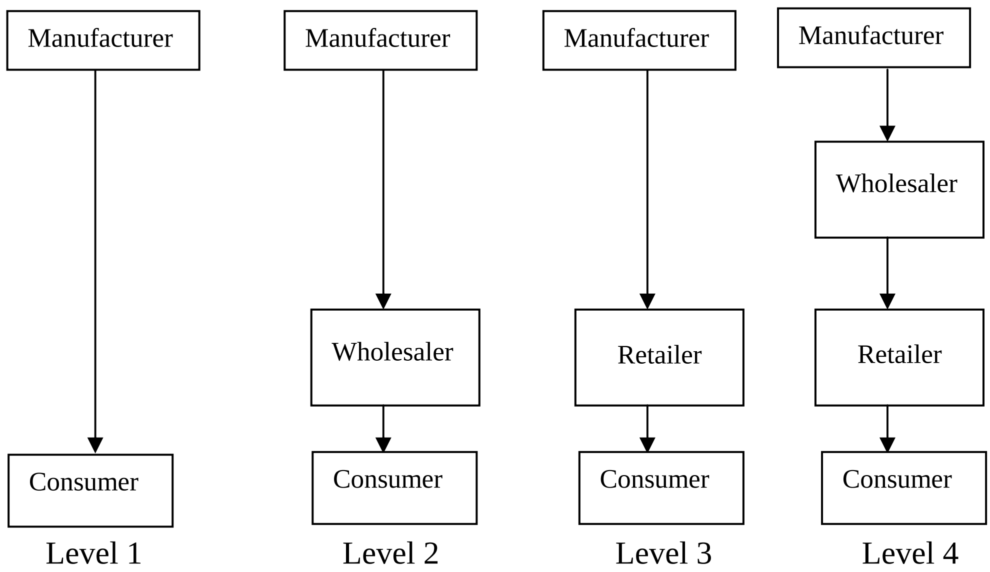

Fig.13.1: Levels of intermediaries

Level 1 represents the direct distribution situation explained earlier in section 13.2; where you choose to sell directly to your customers without using any intermediaries. Levels 2 and 3 represent situations where the manufacturer chooses to sell through wholesalers or retailers directly to a large number of consumers. Level 4 represents multilevel distribution situation where owing to the large market coverage desired, the manufacturer accesses the market through a network of wholesalers who then sell to their respective network of retailers. The retailers then reach out to the final consumers in their respective areas.

13.5 SELECTING AN APPROPRIATE CHANNEL

The channel selection decision is one of the most important decisions that you would be required to take. This is on account of two reasons. One, channel decisions bind you in relatively long term commitments which are usually difficult to undo. Secondly, the costs involved in distribution affect the final price the customers are to pay and therefore, has a bearing on the type of market you will be able to attract at that price. The channel decisions also strongly affect your promotion, pricing and product line extension decisions. These decisions therefore, are taken after a lot of deliberation and consideration .The selection of an appropriate channel design would depend upon:

a) *The market coverage desired:* Your choice of channel design is strongly dependent upon whether you want to operate in the local market only or you desire to operate in regional and national markets as well. As your intended coverage grows, it is difficult and uneconomical to operate only through your own direct channels. Level 3 or level 4 channel systems become more prevalent as the market coverage desired by an entrepreneur grows to regional or national markets.

b) *The resources available at your disposal for production and marketing:* In the initial years, your capacity and resources to produce large quantities of value added products and to market them effectively is rather limited. Direct distribution or shorter channel systems (level 1 or levels 2) to distribute the limited lot sizes being produced by you are more suitable in such circumstances. As the market acceptance grows, entrepreneurs find it more economical to use longer and multilevel channel systems.

c) *The cost of distribution:* In respect of each of the channel systems that you want to use is an important criterion of selection between channel alternatives. As distribution costs form a large percentage of the total cost of goods sold, comparison of different combination of participants in channel systems and the total cost each alternative system should be carried out once you have decided to use intermediaries for the distribution of your value added products.

d) *The type of services that the intermediaries are able to provide to you:* Intermediaries differ in the extent and types of services they are willing to offer to the entrepreneurs. These services range from promotional support to favourable shelf space, refrigeration facilities, cold storage facilities, warehousing, credit support to retailers by wholesalers etc. Depending upon the requirements of your product and marketing effort, you may like to select the channel alternative that best complements your product and marketing needs.

e) *The nature of the product and its shelf life:* Product characteristics often become the starting point in your search for suitable channel alternatives. The nature of the product in terms of its perishability, packaging requirements, shelf life, type of handling required etc are important determinants of what kind of channels or intermediary partners would be most suitable to you . For example, if your value added products are jams or jellies which need to be sold in glass bottles and have a shelf life of about three months, you can afford to be more flexible in your choice of intermediaries but if you are dealing in fruit juices packaged in tetra packs, your choice would be restricted to channel members who can provide refrigeration facilities to ensure that the product to reach the customers in an unspoiled and fresh condition. Similarly, in the cases of products which are equally substitutable by similar competitive products, and have low brand loyalty, entrepreneurs have to resort to intensive distribution to ensure that the consumer does not switch to a competitive product on account of non-availability to their brands.

f) *Buying habits of the customers:* Every marketer needs to study the buying habits of the customers in terms of their shopping preferences, store selection, volume of purchase and frequency of buying. Preferred store choices for food products would be a key input in your choice of the retail level outlets because a new product would get maximum exposure to consumers if it is placed in the outlets frequented by them.

g) *The trade practices followed by your competitors:* When you are in a competitive business like marketing of value added food products, you cannot afford not to be present where your competitor is present in the store outlets, neighbourhood shops, or periodic markets like haats and weekly bazaars. On the other hand, if there are some markets which are overly occupied by a competition, as a new entrant you may find it easier to access other markets where the intensity of competition is lower. In either case, your choice of intermediaries is dictated by the trade practices followed by your competitors.

Typically as new organizations, small firms begin to sell through getting themselves accepted by the existing intermediaries in the local markets; beginning from a limited market access, and by gradually capturing larger markets by diversifying their channel options. You may find that as a new entrepreneur, your problem is often not of selecting appropriate channels but that of being selected by existing intermediaries. Wholesalers and retailers also take the risk when they agree to stock and sell products from unknown new manufacturers especially when the products are eatables like value added food products. You may find that in the initial years you may not have too much of a choice in the selection of your intermediaries. As you get established in the market and your brand starts getting accepted by the consumers, your discretion and flexibility in choosing your own intermediaries will increase.

Motivating the channel members: Once the channel members have been selected and a distribution channel put in place, every manufacturer expects the channel members to provide the best possible support to his products and brands. You would appreciate however that while business from you may be important to the channel intermediary, yours is just one of the brands that he carries. Intermediaries are independent businessmen, engaged in providing distribution support to the manufacturers in lieu of the margins that they can earn from distribution of goods to the final customer. At any given point of time they need to cater to a large number of manufacturers in the same product category, most of them competitors to each other. As an entrepreneur, therefore you would often find that you may need to motivate the channel participants so that there is no laxity in their efforts to push your brands and to create the desired awareness at the point of sale especially when your brand is new. Several approaches are followed by the manufacturers, chief among them being the cooperative approach where the entrepreneur and the channel members get into an agreement whereby the entrepreneur agrees to provide promotional support and assistance, the display materials and equipment if any, commission on extra sales in return for extra efforts by channel members in pushing his products. Use of power, granting of exclusive selling rights, attractive sales promotion schemes directed at the intermediaries, dealer contests etc. are other approaches that used to keep the channel members motivated.

Whether you are conducting your distribution function yourself or following the indirect distribution alternatives through wholesalers and retailers; it is a good idea for you to define the outputs that you want from your distribution network in terms of the service levels that you want to offer to your customers. These outputs could be defined in terms of timeliness of delivery, freshness of stock, information on product and product line, maintenance of complete product line, prevention of stock out conditions etc. Defining these outputs in physical terms will enable you to measure the performance of the distribution effort.

Activity 3

Visit some retail outlets selling value added food products. For the different categories of food products, find out the commission being charged by the retailers from the manufacturers. Also discuss with them to find out the various kinds of support that is being provided by the manufacturer for these products in terms of promotional material, sales display support, sales promotion schemes etc. How in your view the commission given and the support provided affect the selling efforts of the intermediaries?

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13.6 PHYSICAL DISTRIBUTION TASKS: DISTRIBUTION ACTIVITIES AND LOGISTICS

The physical movement of finished products from the point of production to the point of consumption and the associated decisions of maintenance and movement of stocks, handling of material and transportation are included in the physical distribution function, is often called the market logistics function. Physical distribution is an important area of decision making for entrepreneurs who are shocked to often find that it can amount to 30 to 40 percent of the total product cost. Poor functioning of physical distribution activities can lead you to lose customers if you fail to supply goods on time, and create situations where your money is tied up in unsold stocks. The various decisions that you will need to take as a manufacturer of value added food products within the Physical distribution function are the following:

- *Order processing decisions:* The order processing system defines the way your order- to- payment cycle is planned i.e. what is the processing system you would like to put in place once an order is received to the stage where payment for the supply of the order is received. This process may include several steps, from receiving in order to filing it, checking it against available inventory, putting a production schedule in operation if it is a large order, order and invoice shipment, information to the customer for and collection of payment. In case you are selling through the intermediaries, your orders would be received from the intermediaries and the payments in turn would be received from them. Computerization of inventory processes and an order tracking system help in cutting down the order- to- payment cycle considerably and help in saving costs as well as improving the efficiency of the system.

- *Warehousing decisions:* You will find that as a manufacturer of value added products, because of the gap between the time of production and the time of consumption you would need to store finished goods until they are sold. Depending upon whether you are selling only in the local markets or in regional or national markets, you will need to decide on the number and location of warehouses or stocking places where finished goods can be stocked till they are ordered and sold. Small entrepreneurs usually hire space in public warehouses rather than building up their own warehouses. While on one hand more stocking locations mean that that the delivery time to customers will be shorter, it also means that the inventory costs and the warehousing costs would be higher. You could alternatively choose to have a single warehousing location centrally and use quicker transportation modes to deliver the shipments to your various customers.

- *Inventory decisions:* Inventory decisions are important because they represent major cost component of the total cost of distribution. Your inventory decisions include decisions on when to stock and how much to stock of each item. The manufacturers would like the distributors or stocking locations to hold enough stocks of all their value added food products so that the customer orders can be promptly fulfilled. If it is, however, found that holding sufficient stocks of all the items in the product line at all locations is not cost effective. Depending upon the different levels of demand for different items of the product line at different locations in the market, economic order quantities and reorder points are worked out so that overall inventory costs can be minimized.

- *Transportation decisions:* Since goods need to be physically transferred from the point of production to the point of consumption or demand, one of the important physical distribution decisions is that of selecting the mode of transport. In trying to transport your value added food products to your warehouses, your dealers or large customers, if you will be faced with a variety of options like trucks, railways, container services, waterways and airways. The criteria used to selection include cost, speed, reliability, availability and possibility of tracking in- transit information, depending upon their own product based needs, requirements of timeliness of delivery and the weightage they wish to assign to the other criteria, entrepreneurs make their transportation mode selections.

13.7 ISSUES IN THE PHYSICAL DISTRIBUTION PROCESS

There are certain issues that you may need to consider, while taking your physical distribution decisions. Some of the important issues are discussed below:

- The physical distribution objective is often defined as making the goods available in all the places that they are desired in the least possible time at the lowest possible cost. While this looks good on paper, it is something almost impossible to achieve. If you want to make goods available in all possible places where they are needed, and do so in the least possible time you would find that the cost of fast distribution is indeed and not the lowest cost. You will, therefore, have to choose the type of speed of delivery that you desire at the costs that you can afford.

- You will find that there is a certain inter-relationship among the various components of the physical distribution process. A faster transportation mode would mean higher costs of transportation but may result in lower inventory costs. Similarly, higher costs of warehousing may result in lower transportation costs but mean higher inventory costs. Trade offs are therefore, available between different components within the physical distribution function .The relevant cost to look for therefore, is the overall physical distribution cost rather than clicking to minimize the cost of individual components of the physical distribution function.

- In addition to the criteria of cost and timeliness of delivery based on the nature of your product, to which in this case is of semi perishable nature, you may also need to consider competitive criteria- what are the speed and delivery parameters that are being used by the other manufacturers in this business. These parameters sometimes define the trade practice in a given trade

13.8 LET US SUM UP

Distribution performs the vital function of linking the manufacturers with their consumers, by making the goods available at the time at which they are needed by the consumers and at the places at which they are needed. As a manufacturer of value added food products, an entrepreneur has the choice of undertaking the various tasks of distribution himself (Direct distribution) or identifying a suitable combination of intermediaries like wholesalers agents for retailers who will undertake the distribution function for this products in return for the trade commission(indirect distribution). The choice of a suitable channel structure depends upon criteria like the nature of the product, cost, competition, the type of market coverage desired etc. The entrepreneur, in addition, has to decide upon the various components of the physical distribution aspects which include order processing, warehousing, inventory decisions and transportation selection. These decisions are important and need to be taken with serious consideration as physical distribution forms a significant proportion of the total cost of distribution. In this unit you have been exposed to the need and scope of the distribution function, the factors affecting choice between direct and indirect distribution, types of intermediaries and their functions as well as the levels of channels. You have also been exposed to the decisions and issues involved sell for Sussman in the physical distribution function.

13.9 KEY WORDS

Direct distribution : The distribution situation where the entrepreneur chooses to undertake all the distributions functions by himself and sell directly to his customers without involving any intermediaries.

Indirect distribution : The distribution situation where the entrepreneur chooses to sell his value added food products through a network of wholesalers, retailers or agents or a combination of one or more of these intermediaries to form a channel of distribution to reach his customers.

Channel of distribution : A combination of institutions which perform all the activities needed to move a product and its ownership from the point of production to the point of consumption.

Wholesaler : The intermediary who buys from the manufacturer in bulk for the purpose of reselling to the retailers.

Retailer : The intermediary who buys from the wholesalers or directly from the manufacturer for the purpose of selling directly to the consumers.

Physical distribution : The function involved with physical movement of finished goods from the point of production to the point of consumption.

13.10 SELF ASSESSMENT QUESTIONS

1. For the list of products given below, suggest whether direct or indirect distribution channels would be appropriate. Give reasons for your answer.

   a) Fresh fruit juice
   b) Packaged or tinned fruit juice
   c) Jams, jellies or marmalade
   d) Vegetables preserves

e) Pickles
f) Packaged ready to eat vegetables
g) Soup powders

2. As an entrepreneur you have developed a line of fruit based products to suit the health requirements of the present generation. These include a complete range of fruit juices, preserves, jams and jellies without artificial sweeteners or extra sugar. As chemical preservatives have not been used the products have a relatively short shelf life. What are the criteria that you would apply to select appropriate channels for your product line?

3. What are the important decisions within the physical distribution function that an entrepreneur dealing in value added food products will need to take? Explain with the help of suitable examples

13.11 SOME USEFUL BOOKS

1. Barrow, Colin (2000). "The Essence of Small Business" PHI Essence Series.

2. Kotler, Philip (2003). Marketing Management, Eleventh edition, PHI.

3. MS-06 (2003). Marketing for Managers, Block 6 – Distribution Public Policy, IGNOU.

UNIT 14 UNDERSTANDING AND MANAGING PROMOTION

Structure

14.0 OBJECTIVES

After studying this unit, you should be able to:

- discuss the role of promotion in effective marketing of value added products;
- describe the components of the promotion mix;
- decide upon the components that you should use in your promotion effort;
- set up your promotion budgets;
- develop appropriate advertising for your products;
- identify suitable media for your advertising; and
- evaluate your promotion effort.

14.1 INTRODUCTION

Once you have identified what you intend to produce, you also would need to inform the potential customer about the existence and availability of your product, interest them in your product through information about the features of the product, and give them a reason to buy. The entire function of informing the potential and existing market about your offerings, encouraging them to buy your products is referred to as promotion. Promotion is one of the most important elements in the marketing mix. It encompasses all the means of communication with the customers. In accordance with your target market, you need to decide who should inform about the product and what should you tell them. Also, how should you reach these people who may be your potential customers. Promotion is important because it contributes to the consumers' knowledge about the various products available in the market and makes it easier for them to make informed decisions. Promotion is also important because it establishes your product image and brand in the mind of the customer and facilitates the process of remembering and recalling the brand name at the time of decision making. Promotion enables consumers to understand the differences between different product offers and allows you to create an identity distinct from your competitors. For the consumers, it helps them to understand how one brand is different from others, so that they can choose something which most ideally suits their requirements.

14.2 WHAT IS PROMOTION AND HOW ADVERTISING WORKS?

All the processes used by the manufacturers to influence the customer in favour of their products by various means of communication are collectively termed as promotion. Essentially, all products are solutions to the needs of the consumers. At any given time, however, there are several alternative solutions that the customers may have for a given need. The different brands of value added products represent the alternative solutions that the customers may like to choose from. As a marketer, you would need to tell the potential benefits of your product over other competing products. The promotional efforts undertaken by the small entrepreneur can take the form of advertising, publicity, sales promotion or personal selling or a combination of two or more of these. Together these functions constitute the promotion mix for an organisation. Let us try to understand how promotion works.

1. *Creating awareness:* The primary task of promotion or advertising is to create awareness of the product in question for the purpose of increasing the likelihood of purchase of value added products being contemplated by your potential customers. For a new product the marketer's challenge is to create the recognition of the brand name, with simple messages and building recognition of the name over time.

2. *Build knowledge:* Not only is it important for consumer to know your product name, but it is also required that they know what are the features of the product. For example, that it is a quality product with natural ingredients and with no chemical preservatives. Only on the basis of what they know about the product, your consumers will be able to distinguish it from the other products on offer, and decide whether the product would suit their requirements.

3. *Creating liking:* It is the job of the marketer to find out what their potential consumers like in products like jam, marmalade, pickles or juices, incorporate them in the products and then highlight the same in the promotion.

4. *Building preference:* Due to their exposure to your promotion some of the consumers may like the product, but still not prefer it to others. The promotional process, by highlighting features like quality, freshness, taste purity and standardisation of process, attempts to develop a preference for the advertised or promoted product.

5. *Creating conviction:* Through reinforcing the product superiority and making sure the product fulfils the promise created through

communication, promotion also seeks to build up conviction among the target audience over a period of time. You must therefore ensure that the promotion undertaken by you is believable and credible.

6. *Promoting purchase:* Finally, by giving consumers a reason to buy now, or buy a larger quantity or undertake a product trial, either by giving an introductory offer by a promotional discount or a quantity discount promotion aims at influencing purchase of the product.

The above model of how promotion works is called the hierarchy of efforts model. According to another, popular model the AIDA model, promotion works by attracting attention, creating interest, initiating desire and finally buying action.

Activity 1

Make a list of 3 popular brands of juices and fruit preserves. Taking the list with you, ask at least 10 consumers how they first came to know about each brand. Try to learn what they know about the brands, even if they are not using the brand Study this information. What does the information tell you about the role of promotion?

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14.3 COMPONENTS OF THE PROMOTION MIX

In your daily life you are exposed to a variety of promotional efforts by organisations television commercials and print ads, billboards on the road, employment announcements in the paper, 'sale' and discount offers, promotional fliers in your letter box or your e-mail and sales persons knocking at your door are all examples of the promotional efforts being made by the marketers to inform, create awareness, build up preferences and ultimately promote the purchase of their products. To understand different forms of promotion, so that you can utilize them effectively for your own promotional activity, let us define the various components of the promotion mix. As noted earlier, the promotion mix consists of four components i.e. advertising, personal selling, sales promotion and publicity. Each is explained below:

Advertising: It is any paid form of non-personal, mass presentation and promotion of ideas, goods, services by a known sponsor. Advertising may be through any media like newspapers, magazines, posters, bill boards, handbills, television and radio commercials, cinema commercials, direct mailers and e-mail based mailers, catalogues and message on buses, trams, trains etc. Depending upon your budget and the type of audience you want to reach, you may select any combination of forms of the media described above. One basic purpose of advertising is to increase the possibility of purchase and this is sought to be accomplished by imparting information, developing brand awareness and belief, developing favourable attitudes and to influence buying action. You as the marketer would like to inform your potential customers of the availability, prices and the benefits associated with your product so that this information facilitates their selection between various brands. In addition to this basic purpose, you may also use advertising for

a) to announce a special promotion scheme
b) to counteract moves made by your competitors
c) to build up motivation of the retailers to sell your product
d) to encourage and build up the morale of your sales team
e) to build up the image of your company.

Personal selling: In contrast to non-personal mass promotion (i.e. advertising), personal selling is person to person communication between the potential buyer and the seller. It is the oral presentation or oral presentation supported by other media like reports or audio visual slides to one or more potential buyers for the purpose of making a sale. Personal selling as a mode is more flexible than advertising because the salesman can mould his method of presentation and persuasion according to the needs of the customers that he is facing at a given time. In addition to persuading people to buy, personal selling can be used to perform the following functions:

a) Booking orders
b) Generating inquires about the product
c) Answering consumers queries about the use and attributes of the product
d) Price negotiation
e) Collection of payment
f) Collecting market information about customers, competitors and dealers.

Because personal selling uses personal contact as a mode of communication, this is also one of the most expensive methods of promotion specially for low unit value products.

Sales promotion: All marketing activities, other than personal selling, advertising and publicity that are used to stimulate consumer buying and dealer motivation such as incentives, sales displays, shows and exhibitions, coupons, contests, discounts, free sample offers and gift schemes and other non-routine selling activities are included in sales promotion. The purpose of sales promotion is to stimulate the sale of a product by offering some specific incentives which may be directed either at the consumers or the traders. You may also create incentives directed at your own salesmen, stimulating them to sell higher quantities of the product. Generally sales promotion offers give customers a reason to buy now, as the offers are open for a limited period of time. They perform the function of creating an immediate interest and inducing trial of the product. The marketer hopes that once the consumer has tried the product, he will stay with the product since the product is good. There are several types of sales promotion tools. The tools directed at the customer include:

a) Price discounts for a specific period or for a certain package size.
b) Free samples or Subsidised samples.

c) Pack in premium – which is a free gift along with the pack.
d) Quantity offer which allows people to buy extra quantity at no extra cost.
e) Coupons which allow consumers a saving on next purchase or a cash refund.
f) Contests which encourage consumers to enter contest and benefit through games or schemes.

Marketers also use sales promotion directed at their wholesalers and retailers to encourage them to stock sufficient quantities of the product and put in special efforts to sell the product. These sales promotion tools include quantity discounts, display materials, allowances for local advertising, dealer contests and gifts etc.

Publicity: Publicity is defined as non-personal stimulation of demand for a product, service business by generating commercially significant news about it in published media or getting favourable presentation on public media like radio or television. This form of promotion is not by an identified sponsor and is also not paid for by the sponsor.

Today, other elements of the marketing mix are also used as promotional tools. Packaging is an important tool of promotion which can, through distinctive colouring and designing become a special aid in brand recognition and identification. Information on the package and label can play a useful role in creating consumer awareness and knowledge. Attractive package design can stimulate consumer interest. Reusable packages like glass jars and pet bottles add to utility value of the product and add another incentive to purchase.

Public relation, the function of maintaining good relations with general public, customers, press and society at large can contribute to the promotional activity by establishing a favourable image of your organisation.

All these elements together constitute the promotion mix for an organisation. You would need to decide which element or combination of elements you would like to use for your own products, keeping in mind the costs to be incurred, the need for creating awareness and interest and the specific objectives you want to attain through the promotional effort. In the next section, we would discuss the considerations you must keep in mind for deciding on your promotion mix.

Activity 2

Take the example of a few value added products like

a) Branded masala blends (Chat masala, Chana masala etc.)
b) Squashes
c) Fruit juice concentrate

Go through the various media like radio, television and newspapers and identify the types of promotion that is being used for each of these categories. Prepare a brief note on the same, why do you think these elements have been included in the promotion mix?

14.4 DECIDING UPON THE PROMOTION MIX

While attempting activity 2, you would have noted that marketers seldom use only a single element in their promotional efforts. They usually utilize a combination of four elements, depending upon their marketing objectives and resources. If you consider a sample product like Maggie, Noodles, you will find that a combination of television and print advertising, displays in shops, danglers and bill boards, gift schemes and quantity discounts is being used to promote the product. Several considerations affect the type of promotion tools that would be required for a particular product. Let us look at these considerations:

1. *Product considerations:* The type of promotion task to be formed is strongly influenced by the type of product involved. For a low priced, repetitively purchased item like toothpaste or food products, the promotional message would need to be repeated frequently so that consumers are reminded. It would need to reach a large number of consumers so that new consumers can be attracted to the product. As large number of potential customers have to be addressed, person to person methods like personal selling would be unsuitable. You would require elements like advertising and sales promotion to address your promotion needs, newspapers, handbills, posters, free samples radio spots and if you can afford audio visual ads are sources of the alternative you may consider.

2. *Market consideration:* The choice of elements in your promotion mix will also depend upon where your customers are located, are they very widely dispersed, how many target customers do you want to reach, is your target area local, regional or national? How many competitors are already operating in the market place and what are the ways they have chosen to communicate with the consumers? When the target consumer groups are both poor and distributed over a vast geographical area, advertising and sales promotion are more economical and cost effective; as the cost of reach per customer is low. You will find that while personal selling plays a more central role in cultivating customer for industrial goods and even for consumer durable goods, for non-durable low price per unit consumer goods like value added food products, the role of personal selling often gets limited to servicing the wholesalers and retailers.

3. *Resources available:* As an entrepreneur, you would need to set aside resources for promotion. The money you decide to allocate for promotion constitutes your promotional budget. Each of the alternatives studied by you, has its own cost. The extent to which you want to use each element, and the number of elements you want to use at a given point of time, depend upon the size of promotion budget that you have decided for the effect. You will realise that initially your relatively modest budget may allow you only to have localized advertising in the vernacular press, distribution of handbills and displays at the retailer shops. As you grow and develop and are able to assign higher budgets, your choice of elements and the extent to which you want to use them widens.

Product life cycle consideration: All products go through a life cycle of introduction, growth, maturity, saturation and decline. The duration of the stages and the time taken to attain the next stage varies widely with the type of market and the type of marketing strategies applied by the marketers. At each stage, the role of promotion differs. At the introductory and early group promotion has the role of informing the potential customers, creating maximum awareness and building up an interest in the product. The promoting task would require lots of publicity, consumer sales promotion through samples and introductory discounts, informative and creative advertising and promotion directed at the trade. During the late growth and maturity stage, informative advertising is not required, your advertising would be targeted at sustaining consumer preference and building brand loyalty. Looking at your marketing objectives framed, development, growth, stabilisation and survival at different points in the life cycle of your product, you will need to vary the composition of your promotion mix.

Activity 3

Select 5 value added products one each in the product life cycle stages described above. Carefully study the promotional efforts used by them and identify what are the tools used at each stage? Can you reason why this variation exists?

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14.5 SETTING THE ADVERTISING OBJECTIVES

A large number of users of advertising feel that the ultimate objective of advertising is to sell. Advertising seeks to do this though persuasive communication, creating awareness building familiarity and brand recognition and informing consumers from time to time about the comparative advantages of your product over other competing products. Advertising thus has both communication and sales objectives. At any given point of time you may choose to assign more than one communication and sales objectives to your advertising activity. However, for focused effort and effectiveness; it is advisable to define objectives as measurable goals. This is referred to as the DAGMAR approach (defining advertising goals for measured advertising results). The approach suggests that advertising goals should be defined as specific and well defined communication tasks, in measurable terms, which should be stated to be achieved within a specific time period, with respect to a particular set of customers. For your own potential customers, for example, advertising goals could be defined as "to create awareness levels of my brand of Jams and Jellies from the present 0% levels to about 20% among 50% of the target customers in the city of Nagpur and Aurangabad within the next 3 months".

You would appreciate and that when you are about to start your business, the main objective of advertising would be informing your target customers about your products and their features. At the initial stages of the business advertising is designed to create a business and knowledge of your range of products among potential customers. Advertising is essentially a persuasive communication and another objective that is used in the initial stages is to build up the liking, preference and belief in the product and its characteristic in order to motivate customers to initiate purchase. At the later stages when there are several competitors for your products, the objective of advertising would be to compare your product favourably with those of the competitors and getting the customers to learn how to differentiate between your product and the competitors' product. This is known as comparative advertising and the focus is to show the comparison, the advantages of the advertised product over its closest competitors.

Once the product has been accepted in the market, advertising is used to remind people again and again (Reminder advertising) so that the product may remain in the memory of consumers and promote repeat purchases. At subsequent stages in the product life cycle when your objective is to retain the customer your advertising should take the form of reinforcement advertising, and because your goal is to convince the customer that he has indeed made the wise choice by selecting your product.

Your selection of the advertising goals should clearly reflect a clear understanding of your current market situation. If you are in a competitive market and are introducing a new product, the advertising aim would obviously be to create market awareness and give your customer a reason to buy. If you find that the product is getting established but the usage is low then your advertising objectives should be directed at increasing usage.

Your promotional activity is an investment in establishing you in the market by getting you to become known and bringing in the required sales. In order to maximize this investment however you need to be very clear about what exactly you want your advertising to do for you. This clarity will help you in directing your advertising investment towards yielding the most profitable results.

To summarize the objective of the promotion exercise for popularizing your value added products could be the following:

- To inform the market and build awareness of your products.
- To create brand knowledge and help the consumers to differentiate your products.
- To reinforce the positive attitude about your products.
- To motivate consumers to take buying action.
- To build up interest among the dealers and retailers to carry your product.
- To build the image and recall of your product.

14.6 DECIDING UPON THE PROMOTIONAL BUDGET

How does a small business decide how much to spend on promotion? As you have just noted, advertising and promotion are your investments in establishing you in the market. You must set a promotional budget based on your own resources and the objectives of the promotional activity that you have decided for yourself. Some of the methods of deciding promotional budgets used by small businesses include the following:

The affordable method: Small businessmen using this method base their budget on whatever they can afford at a given point of time. While this method is simple, it ignores the reality that when you plan to set up a business to make and market value added products. Your resources are often limited and basing a decision on what you can afford can often leave you with very meagre resources for promotion; whereas your requirements for spending on promotion may be very high because you are new to the market.

Competitive parity method: Some people try to take what their competitors are spending for their own promotion and make this a basis for deciding on their promotional budgets.

Objective and task method: This method allows you to estimate the size of your promotional budget by looking at the tasks and objectives that you have kept for your promotional activity. This method has the advantage that it allows you to adapt your promotion budget according to the tasks that you have assigned to your promotional activity at any given point of time. This is among the most rational methods of arriving at your promotional budget.

Fixed sum per unit method: Under this method the promotional budget is determined by the allocation of fixed rupee amount per unit of product, depending upon the expectation of future sales of the product. This method is also easy to calculate but is arbitrary because it does not take into account the variations needed under given competitive or market circumstances.

Percentage of sales method: In the case of an ongoing business activity, promotional budgets are often decided on the basis of a fixed percentage of sales that you may like to set aside for promotional activity. For example, if you are selling vegetable soup concentrate and your targeted sale for the year is Rs. 2 Lacs, you may decide to spend 5% of your sales for your promotional activities which will give you a budget of Rs. ten thousand. This method also has the advantage of being simple. If you are selling a number of value added products, this five percent may be used as a general guideline for arriving at the promotional budgets for different products, or your overall sales figures may be used as the basis of the total promotional budget for your entire product line. This budgeting method has the advantage of being simple to calculate and easy to administer, but it ignores the market realities and specific requirements that a particular product may have, which may require a different kind of budget than suggested by a standard percentage of sales.

Activity 4

Assume that you are planning to enter the market with a product line of fresh fruit juices and tinned fruit slices. While the fresh fruit juices have a very competitive market, the fruit slices are a relatively new product and there are no major producers in the market. Looking at the methods that you have just studied, how will you decide upon your promotional budget? Identify the method you use and suggest why?

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14.7 SELECTING APPROPRIATE ADVERTISING MESSAGE

The primary purpose of advertising is to help sell your products. Any promotional activity which does not bring the customer nearer to the act of buying is a waste of money. Through your promotion, you should be able to offer a distinctive and attractive proposition by which you can attract your customers to pay attention to what you are saying and ultimately to buy your product. This proposition is called the unique selling proposition (USP) in advertising language. It represents a specific proposition which is distinctive and gives unique information about the attributes of your product which can pull the customers to the advertised product. In the case of value added products, the USP could relate to:

- The freshness of the product.
- The non-use of chemical preservatives.
- The purity of ingredients used.
- The unique flavours developed by you.
- The tamper-proof packaging being offered.
- The unique taste offered by you.
- The pricing advantage offered to the customers.
- Or anything about the product which gives you a uniqueness or a distinctive advantage over your competitors.

In addition, the message in the promotion should be presented in a way that it is able to attract the potential customers to go through the message and help them remember the features of the product. Use of simple language, interesting headlines and attractive visuals showing the product, go a long way in creating effective messages.

14.8 SELECTING SUITABLE MEDIA

There are a variety of media options available for you to take your message across to your targeted customers. Newspapers, radio, television and billboards are some of the most common media used while selecting your media, you should have a clear idea of the media habits of your potential customers – Do they watch Television or listen to the radio and which papers do they read, (most of the literate)? The other factors you would need to consider include the cost of the medium, the reach of the medium, availability of the medium and suitability to your message design. For value added food products, you may like to consider the following media, described below along with their chief characteristics:

Press (including all types of newspaper and magazines): Wide circulation, limited life, is good for mass circulation and reminder messages. You could initially choose local newspapers to cut down on your initial costs and later expand to more regional or national press.

Door to door distribution of pamphlets: Controllable circulation, limited life, and inexpensive and flexible usage are good for mass circulation. These pamphlets can be manually distributed or inserted along with newspapers, with a commission paid to the distribution agents of newspapers.

Direct mail: Restricted circulation, flexible usage and high impact, need prior identification of potential customers. This medium is used by sending promotional letters to identified customers, and is usually applied for high value added customized products.

Outdoor media: Localized circulation is relatively durable and inexpensive and good value reminder as media. Outdoor media include holdings, billboards, posters, neon signs, display cards on buses etc. and wall writings.

Radio: It has wide reach , accessibility across literacy barriers, high flexibility and possibility of quick reminders within no possibility of visual demonstration. On account of its wide reach, radio gives among the lowest cost per listener and is a popular medium among small and new entrepreneurs.

Television: Combines the advantages of both audio and video but expensive medium with limited reach and high degree of viewer involvement. It is very suitable for product demonstration.

Cinema: Reach is limited to the cinema going population not all of whom maybe your potential customers. It reaches literate, neo literate, and illiterate audience.

Miscellaneous media: Media like exhibitions, fairs, haats and weekly bazaars offer good opportunities for promoting low unit value products like value added fruit and vegetable products.

For promoting your value added food products, you can select one or a combination of some of the above media on the basis of their effectiveness in reaching your promotion messages to your target audience. Due to the cost constraints, some of the expensive media like television or national dailies maybe unaffordable at the initial stages of the business. In fact, if in the initial stages you are catering primarily to the local markets, more localized media like outdoor media, pamphlets, local bazaars and radio may be more suitable as your media choices to begin with.

14.9 COORDINATING WITH THE ADVERTISING AGENCY

As you would have realized, most of the promotional activity is a specialized one. It is therefore, advisable to engage an advertising agency to design and release your advertisements and organise other promotion as per your requirements. An advertising agency is an independent business organization comprising creative and business people to design, develop, prepare and place advertisements in media for their clients seeking to find customers for their products. Copy writing for ads, buying media space, planning media schedules, conducting marketing research to know the consumers better, public relations etc are all highly specialized activities, and are better left to specialized functionaries in the agency itself.

In order to get the best work out of the agency; you need to work closely with the agency. It is a good practice to get your requirements and ideas regarding your product and the way you want them to be promoted, across very clearly during the first meeting with the agency. At the initial stage you may have to set aside a lot of time and information to help the agency to have a complete understanding of your business, your marketing targets and the precise way in which you want your products to be presented to the customers. Usually the work of a specific client is entrusted to a given executive called the account manager for, who handles all the activities related to that account. It helps if close communication can be setup with this account manager so that your coordination with the agency can be easy and effective.

14.10 ROLE OF PUBLICITY IN PROMOTION

As noted earlier in the beginning of this unit, publicity is the non-personal stimulation of demand for a product or business unit by placing commercially significant news about it in a published medium or by obtaining a favourable presentation on it on radio, television or stage, which is not paid for by the sponsor of the promotion.

Publicity is essentially aimed at building up a favourable image, creating goodwill and getting a positive visibility which helps the business in its marketing efforts. Publicity is specially useful in creating a favourable information dissemination about new products, special features introduced, special R&D efforts made in value addition, promotion of new trademarks and brand images.

Publicity is also used to counter any misinformation misgiving or negative information in the market about a particular product or a brand or the business. As publicity is not paid for, and is seen to emanate from a neutral and impartial source, it can be an extremely powerful tool and should be used carefully for maximum impact.

Activity 5

Identify, by reading newspapers or magazines some publicity releases about value added food products. Explain how the printed material which has come out as an article on news item would help the product in question.

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14.11 ROLE OF PERSONAL SELLING

While advertising and publicity are impersonal methods of mass communication, personal selling uses face to face personal communication with target customers. As a manufacturer of value added food products, you may need to personally convince large dealers and big retailers to carry your product line. The scope of the personal selling activity for consumer goods includes obtaining periodic orders, ensuring timely supplies, helping dealers with desired style of display and building up a personal network of dealer relationships over time. If you decide to use personal selling as part of your promotional activity, you could often find that while it is costly in terms of time & effort, it helps to get valuable feedback and market information about your customers and competitors. You are also able to monitor the movement of your goods and assess the relative performance of the various products in your product line.

In order to perform the PERSONAL selling function well, you need to

- know your own product extremely well, specially in terms of how it is better or different from the competitor's product;
- know your competing products well;
- know the trade practices regarding margins to be paid and credit to be allowed to the distributors and retailers;
- listen carefully to what your customers need;
- collect information about what is the consumption pattern shown by your distributors;
- address your customers with due courtesy and regard;

- highlight the advantages of your product compared with your competitor's products;
- be persuasive and make persistent efforts to get the orders; and
- always highlight your unique selling proposition, if any.

14.12 ROLE OF SALES PROMOTION

As explained in the initial part of this unit, sales promotion refers to all promotional activities which are designed to stimulate the features of a product by offering some kind of incentives. The incentives may be directed at the target customers or the dealers. Sales promotion is usually of a short duration and the schemes announced have a fixed time within which they will be operational. By using sales promotion, you not only provide the customer a reason to buy, but also a reason to buy now or buy a far larger quantity than he or she would otherwise have bought. You may, as the producer of value added food products, need to some times offer incentives to move your products fast into the market. Let us identify some of the sales promotion methods that can be used by you. The sales promotion methods directed at the consumers include the following:

- *Price off schemes:* These offer a price discount for a specific period. You may use the scheme as an inaugural discount or as a discount on large purchases.
- *Samples:* Samples involve free distribution or subsidized distribution of small quantities of your products to your potential customers to let them have an idea of what the product is like. Samples enable customers to taste the product and check the quality by themselves.
- *Pack in premium:* Such schemes involve the offer of a free article along with the product for example, a free teaspoon or a bowl along with a jar of fruit preserve.
- *Quantity off:* These schemes offer extra quantity at no extra cost.
- *Coupons:* Coupons entitle the buyer to a stated saving on the purchase or the future purchase of the product.
- *Cash refund offers:* These offers are also like coupons except that in this case the refund in cash form is made after the purchase
- *Contests and games:* Such schemes invite the customers to participate in a contest or a game and some are given prizes through a lucky draw or some other objective method. Such contests get very popular among children and are an excellent device to popularize a new product or gain wide awareness among consumers.

Sales promotion schemes may also be directed at your dealers or sales persons. Buying allowances, free goods, display material, and sales contests are some of the common trade promotions used by small businessmen and entrepreneurs.

Activity 6

Make a quick survey of recent newspaper advertisements or TV advertisements to identify some of the sales promotion schemes that are used for food products. In your view, what are that types of schemes that are most common in the case of such products? What do you think is the impact of such schemes on potential customers?

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14.13 EVALUATING THE EFFECTIVENESS OF YOUR PROMOTIONAL EFFORT

As a manufacturer of value added products, who has put in effort and resources towards promoting his products, you may like to find out whether your promotional effort has been effective or not. One of the most common indicators that people try to use is the increase in sales, but you would agree that there is always a time lag between advertising effort and sales results. Let us understand how can you evaluate whether your promotion has been effective?

While discussing the objectives of promotion in the beginning of this unit, it was pointed out that promotion could have two types of objectives, the communication objectives and the sales related objectives. Under the same section the DAGMAR approach to promotion objectives was also explained. Your task of measuring the effectiveness of your promotion would be strongly dependent upon the precise objectives that you defined for the promotional activity. You can therefore, measure the effectiveness of promotion by

- Measuring the communication effectiveness of promotion.
- Measuring the sales effect of promotion.
- Measuring the relative impact of different media used by you.

The communication effectiveness of promotion is measured by testing the awareness levels of your target customers about your product before and after the promotion campaign, or recall and recognition levels of your brand, based on the objectives defined by you.

Sales are a result of both promotion as well as other elements of your marketing effort. It is therefore, usually difficult to isolate the effect of only the promotional inputs. The fact that there is a time lag between the effort made and the resulting sales, makes the situation even more complicated. The sales effect of advertising is measured by the regression analysis over time. However, sales effect of specific schemes used is easier to calculate. For example, if you have used direct mail as your promotion method, the sales orders received as a response would let you judge the effectiveness of your promotion in terms of sales effect. Again, if you have used coupons as a sales promotion method, the number of coupons received by you becomes a direct measure of the sales resulting on account of the coupons

Manufactures also use different levels of promotional effort or different kinds of appeals in different market territories to compare and measure the sales effect of these efforts.

14.14 LET US SUM UP

In this unit, an effort has been made to introduce to you the basic components of the promotion mix that can be used by you to promote the sales of your product in the market and establish your market identity among your customers. The role of each of these components has been discussed. The important decisions in your promotional activity, right from deciding upon the promotion mix and setting up the promotion budgets to evaluating the effectiveness of your promotion have been discussed at length. The unit also tries to give you an idea of the different media that can be used for low units value items like food products.

14.15 SELF ASSESSMENT QUESTIONS

1. What is the significance of promotion in the effective marketing of value added food products? Explain with the help of suitable examples.

2. How do advertising and promotion work? What is the kind of effect that these may have on consumers of your products?

3. What do you understand by the term promotion mix? What are the components of the promotion mix?

4. What are the factors that help you decide upon the design of your promotion mix? Assume that you are a manufacturer of several types of sauces and spice blends. While spice blends from other manufacturers are also available, your sauces are unique and innovative. They are targeted at the high end market. Explain the factors you would consider while selecting your promotion mix. Also specify what type of components would you use in your promotion and why?

5. How would you decide your promotion Objectives? Discuss with reference to the product you want to promote in the market place.

6. What are the media options available to producers of value added food products who want to promote their products?

   a) On our nation-wide basis?
   b) In the local markets?
   c) In the export market?

   Explain with reference to specific product examples chosen by you.

7. How can the effectiveness of promotion be evaluated? Explain with the help of suitable examples.

UNIT 15 PERFORMANCE MEASUREMENT AND CONTROL

Structure

15.0 OBJECTIVES

After studying this unit, you should be able to:

- understand the relationship between planning and controlling;
- comprehend the meaning and need for measuring performance;
- get a clear view of the performance measures;
- understand the concept of controlling and its procedure;
- know about the procedure of controlling; and
- have an insight into the important tools and techniques of controlling.

15.1 INTRODUCTION

A businessman has always to look ahead in terms of production, sales, expenses, profitability, customers, etc. In the process of looking forward and assessing his future he should be mindful of various activities happening in his firm. He should occasionally, stop and review his previous activities to see whether his business is running on the right track as he desired or not. Planning is important but review of measurement of performance and its control is also equally important. Both of them are in fact complementary and supplementary to one another. Controlling is effective only when there is proper planning, and planning is fruitful only when there is effective control. The inter-dependency of planning and control can be shown through the following diagram.

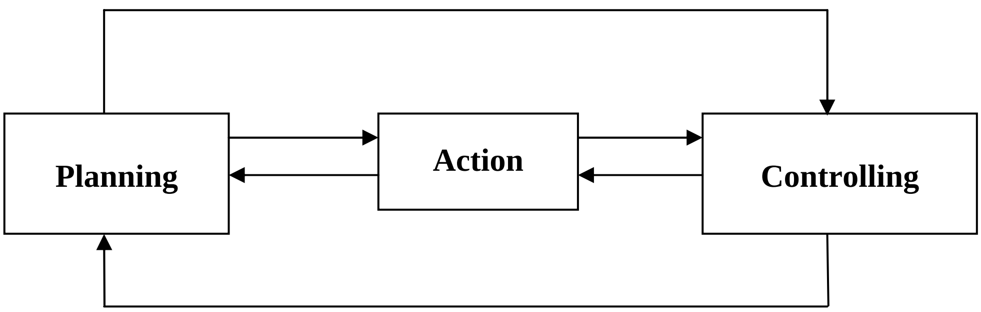

Figure 15.1: Diagram showing inter-dependency of planning and control

Performance Measurement

In this Unit you will learn the importance of performance measurement and control.

Meaning

Performance measurement is a management function. It helps in detecting, preventing or eliminating distortions in the process or product. The aim is to match the product to the customer's requirements. Performance measurement makes the organization capable of taking sound decisions about the action to be taken to ensure appropriate processes and products.

Need for Measuring Performance

If an activity cannot be measured, its effect cannot be seen and suitable correctives cannot be applied. The activity cannot then be controlled and managed.

What are performance measures

A performance measure is composed of a 'number' and a 'unit of measure'. The number gives us a magnitude (how much) and the unit gives the number a meaning (what). Performance measures are always tied to a goal (the target). These can be represented by hours, meters, number of reports, units of product manufactured etc. They can show the variation from the standards set.

Two types of unit of measures are used:

i) single-dimensional unit of measure;
ii) multi-dimensional units of measure.

In case of single dimensional units, performance measures can be represented by units like hours, meters, rupees, number of reports, etc. They can show the variation in a process. Single-dimensional units of measure usually represent basic measures of some process or product.

In case of multidimensional units of measure, performance measures are expressed as ratios of two or more basic units. These may be units like number of bottles of jam produced per month, number of hours worked to produce a packet of papads, etc. Performance measures expressed this way convey more information than the single-dimensional or single-unit performance measures.

Foundation for a Performance Measurement System

Successful performance measurement systems are based on the following principles:

1. A businessman should focus on customer needs and based on that measure what is needed to be measured.

2. A businessman should measure only that which is important and will affect customers' satisfaction.

3. A businessman should involve employees/workers in the design and implementation of the measurement system. He should give them a sense of purposeful control, which will lead to improvement in the quality of the measurement system.

Benefits of Performance Measurement

1. *To ensure that the decisions are based on facts*

   The businessman can ensure that his decisions are based upon well-documented facts and figures and not on intuition and gut feelings.

2. *To show the areas of improvements*

   Performance measurement can show the areas where improvements need to be made. The businessman can come to know where he can do better or how he can improve.

3. *To reveal the clear picture of improvements*

   Based on measurement of performance the businessman can have a clear picture whether the improvements have actually occurred or not.

4. *To reveal incorrect assumptions*

   If the businessman has been doing his business for a long time, he might have been assuming incorrectly that things are going well, whereas in actuality that may not be the case. Thus, without measurements there is no way to tell whether the business cannot do better.

Performance Measures

Performance measures are generally expressed in terms of quantity. They provide useful information to the businessman so that he may make intelligent decisions about his business. They tell him something important quantitatively about the processes with the help of which products are manufactured. In a nutshell, performance measures tell him:

- how well he is doing;
- if he is meeting his goals;
- if his customers are satisfied;
- if his processes are well in control;
- if and where improvements are necessary.

Features of an ideal unit of measure

Following are the features of an ideal unit of measure:

1. It should be understandable.
2. It should reflect the needs of the business.
3. It should reflect the customer's needs.
4. It should be capable of wide application.
5. It should be interpreted uniformly.
6. It should be precise in interpreting the results.
7. It should be economical to apply i.e. its should be cost effective.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Fill in the blanks:

   a) Performance measure can be used for exercising ____________.

   b) A performance measure is composed of a number and a ___________.

   c) 'Hours' is an example of ______________________ dimensional unit of measurement.

   d) Performance measures are generally expressed in __________________.

   e) A performance measure should reflect the needs of the ______________ and the business.

2. State True or False:

   a) A businessman should measure only important activities of the firm.

   b) A businessman should involve the employees in the formulation of measurement system.

   c) An ideal unit of measurement should be expensive to apply.

   d) Single-dimensional unit of measure conveys more information than multi-dimensional unit of measure.

   e) Measurement of performance does not provide a clear picture whether the improvement has actually taken place or not.

3. Name any two performance measures.

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15.2 MEANING AND FEATURES OF CONTROLLING

Let's go down the memory lane. Think of those days when you were in Class XII studying for your first terminal examination. You decided to secure 75% marks in aggregate and started studying accordingly. When you received your Report Card you were shocked because you could manage to get only 60% instead. After certain hue and cry you must have sat down and thought that where you went wrong –

- Whether your scheduling was incorrect; or
- Whether your syllabus was too heavy; or
- Whether you got nervous right at time of examination; or
- Whether you had not revised the lessons thoroughly.

Lastly, you must have made fresh plans to do better at the next terminal examination by making a proper timetable, by revising the lessons thoroughly and by streamlining your study pattern.

In the above process you have unknowingly applied the controlling procedure.

Controlling Defined

Controlling is nothing else but to set standards, measure the performance, compare the performance with the standards set and take corrective measures if deviations are found. In other words controlling is comparing operating results with the plans and taking corrective action when result deviates from the plan. Thus, controlling is an 'action oriented' process.

Control process can be illustrated with the help of an example of automatic iron, which is fitted with thermostat. As soon as the iron is switched on the bulb lights up – it means that the current is passing in the iron. The current goes on passing as long as the temperature does not reach the level at which the thermostat is set. Immediately after the temperature reaches that level, the thermostat starts functioning and the current is disconnected, thereby causing the bulb to go off. When the temperature becomes low than the level set, the thermostat allows again the current to pass and the bulb lights up. Here, the thermostat is acting like a controlling device, which compares the actual performance with the standard set. It starts functioning and disconnects the electric current when the actual deviates from the standard.

Features of Controlling

- It is the last function of management process, the first function being planning.
- It is a dynamic process, adapting itself to the changes in the environment.
- It is a continuing process.
- It is pervasive in nature i.e. it is found at all the levels of management.
- It is backward looking because it involves feedback and responses. It is linked with – what has happened in the past.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why is controlling referred to as 'backward looking'.

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2. Mention two features of controlling.

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3. If controlling is said to be the last function of management process then which one is the first function?

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15.3 PROCEDURE OF CONTROLLING

Let's now discuss the control process. It embraces the following steps:

i) Fixing standards

Standards serve as a test of performance. It is a criterion against which results are measured. Standards can be expressed in physical terms and monetary terms. If we say that the firm is required to manufacture 1000 packets of tomato puree in a week, this is expressing standards in physical terms. In case the standard set is to increase the sales by Rs. 10,00,000 by the end of the current financial year, this is expressing standards in monetary terms.

The standards should be easily understandable, result-oriented and attainable. They should be scientifically set with the help of time and motion studies. Workers should also be consulted in order to involve them in achieving the standards set.

In general, good performance standards should have the following attributes:

- *Understandable:* Standards should be expressed in simple and clear terms, so as to avoid misinterpretation or vagueness. Similarly, instructions for their use should be specific and complete.
- *Attainable:* Standards should be such that they can be attained with reasonable efforts under the given conditions.
- *Economical:* Cost of setting and administering the standards should be low in relation to the activity covered and the benefit to be derived.
- *Applicable:* Standards should be such that they can fit the conditions under which they are to be used. If conditions vary, they should contain built-in flexibility to meet these variables.
- *Consistent:* Standards should help to unify communication and operations throughout all functions of the company.
- *Stable:* Standards should have a fairly long life to provide comparability.
- *Adaptable:* Standards should be designed in such a way that elements can be added, changed, and brought up-to-date without much complexity.

- *Equitable:* Standards should be accepted as a fair basis for comparison by the people who have been assigned the responsibility of meeting the goals.

- *Customer-focus:* Standards should address areas, which are important to the customer (internal/external) such as cycle time, quality, cost schedule performance, and customer satisfaction.

ii) Measurement of performance

Performance can be measured through inspection, observation, measurement and reporting. Uniform reports should be prepared at regular intervals. Performance measurement should be an ongoing process. It is easier to measure the standards if they are tangible in nature. For example, Rahul & Co. sets the standard to reduce the advertisement expenses by Rs. 50,000 in the next six months. This standard being tangible can be easily measured with the actual performance by looking at the figures of actual advertisement expenses. But, in cases where standards are not tangible like result expected from a training programme for salesmen, measurement of results becomes complicated.

iii) Comparison with actual performance

The actual performance should be measured with the standard set. If deviations are found exceptionally wide then only should be concentrated upon. It helps in conserving time and effort of the businessman. For long-run standards (like increase in return on investment) annual comparison may not at all be appropriate. But in case of short-run standards (like to maintain a minimum cash balance of Rs. 1000) comparison can be on daily basis. For certain short-run standards comparison can be on weekly or monthly basis e.g. to reduce the selling and distribution expenses by 2% within a period of 4 months.

iv) Finding the cause of deviation

A very wide range of deviation is analysed at this stage. It is done so to find out the various reasons of its occurring. This analysis should be promptly done to make control effective.

v) Taking corrective actions

Remedial action is to be taken so that deviations may not occur again and objectives are properly achieved. Corrective action may involve:

- *Let the situation remain as it is:* This is applicable if the deviation is insignificant i.e. within tolerable limits (which should be set in advance).

- *Correct the deviation:* This can be done by improving the performance e.g. defective tools to be repaired, generators to be installed, close supervision, incentives to be provided, appointing more salesmen, good training provided etc.

- *Revision of standards:* The standards may need to be revised if they are not effective for required control.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write any two examples of standards which can be easily measured and compared.

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2. What will be the consequence if the standards fixed are on higher side?

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3. Why the reporting should be quick?

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15.4 TOOLS AND TECHNIQUES OF CONTROLLING

1. Ratio Analysis

Ratio analysis is a study of relationship among various financial factors in a business like sales, gross profit, net profit, stock, debtors, fixed assets etc. It is a technique of analysing the financial statements by computation of ratios. Ratio analysis acts as an important and effective control device in an organization. It is the process of establishing a significant relationship between the items of financial statements to provide a meaningful understanding of the performance and financial position of a firm. Ratio analysis focuses attention on relative figures which should be significantly related. For example, figure of sales when related to the figure of gross profit will indicate gross margin earned on sales. This means both the figures in the ratio are significantly related. Ratio analysis seeks to measure the effectiveness and profitability of the various functions.

Controlling process starts when the accounting ratios are compared with their own past ratios or with the ratios of similar firms in the same industry. For example, a Fruit Jelly manufacturer measures that his gross profit ratio for current year is 18% whereas in the immediate past year it was 22%. Thus, on comparing the gross profit ratio he finds the deviation. Now he has to take remedial action to improve the ratio.

Some of the important ratios used in controlling the affairs of a business are:

i) Return on Investments (ROI)
ii) Net profit to Sales (Net Profit Ratio)
iii) Sales to Capital employed (Capital Turnover Ratio)
iv) Gross profit to Sales (Gross Profit Ratio)
v) Sales to Working Capital Ratio (Working Capital Turnover Ratio)
vi) Stock Turnover Ratio
vii) Operating Ratio
viii) Current Ratio
ix) Debtors' Turnover Ratio

Let's now discuss these ratios.

i) Return on Investments (ROI)

This ratio shows the relationship between net profit (before interest and tax) and capital employed. It indicates how efficiently the capital employed in the business has been used. In other words it shows the firm's ability to generate profit per rupee of capital employed. It is a measure of overall profitability of an enterprise. Higher the ratio the better it is.

Formula: $\text{Return on Investments (ROI)} = \frac{\text{Net profit (before interest and tax)}}{\text{Capital employed}} \times 100$

where Capital employed = Fixed assets + Working capital

For example, a company manufacturing various bakery items has earned a net profit (before interest and tax) of Rs. 4,00,000 during the current financial year. The company has Rs. 16,00,000 as capital employed. The ROI works out to 25%. In the same industry ROI is 20%. This means the company has used its capital efficiently.

ii) Net Profit to Sales (Net profit ratio)

This ratio shows the relationship between net profit and net sales. It measures the rate of net profit on net sales. It helps in ascertaining the efficiency with which the affairs of the firm are being managed particularly its marketing. In case the ratio increases, it indicates improvement whereas if it declines, it reveals inefficiency in the management of the affairs of the firm.

Formula: $\text{Net Profit Ratio} = \text{Net Profit/Net Sales} * 100 = \frac{\text{Net profit}}{\text{Net sales}} \times 100$

For example, the net profit of a firm is Rs. 1,00,000 and the net sales is Rs. 4,00,000. In this case, the Net Profit Ratio is 25% as calculated below:

$$\text{Net Profit Ratio} = 1{,}00{,}000 / 4{,}00{,}000 * 100 = 25\% = \frac{1{,}00{,}000}{4{,}00{,}000} \times 100 = 25\%$$

In the corresponding next year, if the Net Profit Ratio works out to 30% it will show efficiency in the management of the affairs of the firm.

iii) *Sales to Capital Employed (Capital Turnover Ratio)*

This ratio shows the relationship between net sales and capital employed. It indicates the firm's ability to generate sales per rupee of capital employed. Higher the ratio the better it is.

Formula: $\text{Capital Turnover Ratio} = \dfrac{\text{Net sales}}{\text{Capital employed}}$

where Capital employed = Fixed assets + Working capital

For example, net sales of a company is Rs. 8,00,000. The company has Rs. 2,00,000 as capital employed. The Sales to Capital employed (Capital Turnover Ratio) works out to 4 times. i.e.

$$\frac{8{,}00{,}000}{2{,}00{,}000} = 4$$

iv) *Gross Profit to Sales (Gross Profit Ratio)*

This ratio shows the relationship between gross profit and net sales. It indicates the gross margin earned on sales.

Formula: $\text{Gross Profit Ratio (GP Ratio)} = \dfrac{\text{Gross profit}}{\text{Net sales}} \times 100$

For example, a spices manufacturing unit earns a gross profit of Rs. 5,00,000 during the current financial year. Its net sales (i.e. gross sales – sales returns) are Rs. 25,00,000. In this case the GP ratio works out to 20%. Higher the ratio the better it is.

v) *Sales to Working Capital Ratio (Working Capital Turnover Ratio)*

This ratio shows the relationship between net sales and the working capital. It indicates the efficiency with which the firm has utilised its working capital. In other words it signifies the ability of the firm to generate sales per rupee of working capital. Higher the ratio the better it is.

Formula: $\text{Working Capital Turnover Ratio} = \dfrac{\text{Net sales}}{\text{Working capital}} \times 100$

where Working capital = Current assets – Current liabilities

For example, a grocery dealer's sales during the current financial year are Rs. 18,00,000. His working capital is Rs. 6,00,000. In this case Sales to Working Capital Ratio (Working Capital Turnover Ratio) works out to 3 times.

vi) *Stock Turnover Ratio*

This ratio shows the relationship between cost of goods sold and the average stock. It indicates the efficiency with which the firm has utilised its stock. In other words it signifies the speed with which stock is converted into sales. Higher the ratio the better it is.

Formula: $\text{Stock Turnover Ratio} = \dfrac{\text{Cost of goods sold}}{\text{Average stock}}$

where (i) Cost of goods sold = Opening Stock + Purchases + Direct Expenses – Closing Stock and (ii) Average Stock = (Opening Stock + Closing Stock) / 2.

For example a mango juice manufacturer's cost of goods sold during the current financial year amounted to Rs. 10,00,000. His average stock during this period was Rs. 2,00,000. In this case Stock Turnover Ratio works out to 5 times.

vii) Operating Ratio

This ratio measures the relationship between operating cost and net sales. It indicates the operational efficiency with which the production or purchases or selling operations are carried on. Lower the ratio the better it is.

Formula: $\text{Operating ratio} = \dfrac{\text{Operating cost}}{\text{Net sales}} \times 100$

where (i) Operating Cost = Cost of goods sold + other operating expenses like administrative expenses, selling and distribution expenses etc.

For example a tomato puree manufacturer's cost of goods sold during the current financial year amounted to Rs 10,00,000 and other operating expenses were Rs. 75,000. His sales during this period were Rs. 25,00,000 whereas sales returns were Rs. 50,000. In this case the operating ratio works out to 43.88% as calculated below:

Operating Ratio = 10,75,000/24,50,000*100 = 43.88%.

viii) Current Ratio

This ratio measures the relationship between current assets and current liabilities. It indicates the ability of the firm to meet its short term obligations. In other words it shows short term financial solvency of the firm. Ideal current ratio is 2:1.

Formula: $\text{Current Ratio} = \dfrac{\text{Current assets}}{\text{Current liabilities}}$

where (i) Current assets = Cash and bank balance, marketable securities, debtors, bills receivables, stock, prepaid expenses etc. and (ii) Current liabilities = creditors, bills payable, bank overdraft, short term loans etc.

For example a ginger and garlic paste manufacturer's current assets as on 31st March 2004 were Rs. 6,00,000 and current liabilities were Rs. 3,00,000. In this case the current ratio works out to 2:1.

ix) Debtors' Turnover Ratio

This ratio measures the relationship between net credit sales and average debtors. It indicates the ability of the firm to collect its trade debtors. In other words it shows the speed with which the debtors are collected. A high ratio indicates shorter collection period i.e. debtors are repaying promptly.

Formula: $\text{Debtors' Turnover Ratio} = \dfrac{\text{Net credit sales}}{\text{Average debtors}}$

Where Average Debtors = Opening Debtors (including opening bills receivable) + Closing Debtors (including closing bills receivable) / 2.

For example a 'sarson' oil manufacturer's net credit sales for the year 2004 were Rs. 90,00,000 and average debtors were Rs. 15,00,000. In this case the Debtors' Turnover Ratio works out to 6 times.

2. Cost Analysis and Control

This analysis is associated with various costs of the firm. Cost control is important because all the businessmen – whether operating on a small scale or large scale – always try to contain their all types of costs. For a successful analysis, the businessman should himself have a very clear idea of all the costs. He should also have an effective system to measure and analyse them systematically. Various costs may include – cost of production; cost of credit sales; selling and distribution costs; inventory costs; channel costs; marketing research costs; advertising costs; sales promotion costs etc.

These costs should be measured against the results produced by incurring them. The results may take the form of sales revenue generated, gross profit achieved etc. The efficiency of each product, channel, customer-class, and salesmen should be analysed by measuring their respective contribution to profit of the firm on the one hand and to the overheads on the other.

Cost analysis should also include standard costing for various management functions. It is not enough that costs should be compared with the budgeted costs only. The firm should develop standard costs for each function of market and measure actual cost with the standards set.

Cost analysis helps the businessman in the following ways:

- It helps to control and reduce all types of costs.
- Cost reduction leads to savings.
- It leads to alternate ways of performing functions to reduce the costs.
- Prices can be kept at competitive rates if costs are reduced.
- The businessman can drop unprofitable customers, products, dealers etc. from the list.

3. Credit Control System

A businessman generally prefers to sell his goods on cash basis. It is because of the following reasons:

- No risk of bad debts.
- Less working capital required because of continuous cash generation.
- Short operating cycle.

Despite above advantages of selling goods on cash basis, the businessman may still be forced to sell goods on credit basis on instalment basis to achieve higher turnover. There may be number of problems attached to the selling of goods on credit or instalment basis like:

- Interest on money involved.
- Money blocked for longer period of time.
- Legal hassles i.e. court cases if money is not realized.
- Loss due to insolvency of debtors.
- More accounting work involved.

Despite these problems a businessman sells his goods on credit or instalment basis because he has to survive in the market, and higher turnover may offset losses and such sales.

In case he sells his goods on credit basis, he should frame a clear credit policy. The businessman should also have a proper credit control system on the following lines:

i) Credit should be extended to the customers and dealers after a proper credit rating is made. A credit rating analysis would reveal the soundness of the customers and dealers. No-risk customers may be extended large credit limits. High-risk customers could be given credit only if bank guarantee or collateral security is made available.

ii) The businessman should also adhere to the prescribed credit limits.

iii) As a part of credit control system he should analyse the accounts receivables and bad debts. The number, type, extent and integrity of the debtors or the reason for a debt to become bad must be brought out by the analysis. The age of debtors outstanding should be determined (i.e. 15 days old debts, 30 days old debts, 45 days old debts, 180 days old debts, 365 days old debts etc.) from time to time and based on this analysis corrective action should be taken.

iv) A proper credit control system will ensure that the cost of credit is built to the price itself.

v) Strategies like offering cash rebates in lieu of credit can be thought of. Cash discounts may be offered for quick recoveries.

4. Budgetary Control

A budget is a plan for some specific future period. It is based on objective to be attained. It is expressed in monetary or physical units. A budgetary control is a system in which all operations are forecast and planned and the actual results are compared with the forecast and the planned ones for reviewing policy are programme for the balance period or for next period.

Budgetary control can be applied to every function of the business i.e. production, finance, human resources, marketing etc. It corrects the deviations from pre-planned path through observation, research, reporting, planning and decision making. The future activities of the business can thus, be performed in an orderly way.

The procedure of budgetary control involves the following steps:

i) Establishing the budgets.

ii) Continuous comparison of actuals with budgets by preparing control statements which will show:

- Budgeted figures
- Achieved figures
- Variances

iii) Placing the responsibility for failure to achieve the budgeted figures.

iv) Revision of budgets.

Advantages of budgetary control.

Following are the advantages of budgetary control:

i) It helps in bringing efficiency and economy in the working of the business enterprise.

ii) It fixes responsibility on every division or department of the enterprise.

iii) It coordinates the various divisions of a business i.e. production, marketing etc.

iv) It serves as an automatic check on the decisions of the management.

v) Credit agencies favour that organisation which operates through a well-ordered budget plan.

5. Break-even Analysis

Break-even analysis is yet another controlling device which can be used by a businessman. It is an important tool of profit planning. It is also called cost-volume-profit (CVP) analysis. It facilitates cost control by measuring operational efficiency. At break-even point the businessman neither makes profit nor incurs losses. For calculating break-even point we need to understand the following concepts:

i) Fixed costs (FC): Fixed costs are those costs which remain constant whether there is increase or decrease in production over a given period of time. These costs are fixed in nature and are incurred as soon as the business is started. This concept of fixed costs remains valid up to a particular level of operation.

Examples of fixed costs are – rent of the premises, salaries of the employees, depreciation, interest charges on long term debts, insurance premium, property tax etc. Even if there is no production, these fixed costs will be incurred. Suppose, a jam manufacturer incurs Rs. 40,000 towards fixed costs for manufacturing jam bottles. In this case fixed costs are Rs. 40,000 which shall be considered for calculating break-even point.

ii) Variable costs (VC): Variable costs are those costs which vary according to the level of production attained. They will increase if the production is increased even by one unit or decrease when there is decrease in production.

Such costs are – raw material costs, wages to the workers, water charges, oil and fuel etc.

For calculating break-even point, generally we consider variable cost per unit of production. Suppose variable cost incurred for manufacturing 1000 jam bottles is Rs. 55,000. In this case per unit variable cost works out to Rs. 55.

Note: For the purpose of calculating total cost of production we have to add fixed cost and variable cost. Thus,

Total Cost = Fixed cost (FC) + Variable cost (VC)

iii) *Selling price:* Selling price is that price at which the goods are sold. Usually, we consider selling price per unit for calculating break-even point. For example, a jam bottle is priced at Rs. 75. It means that it will be sold to the consumers at this price. Thus Rs. 75 is the selling price per unit of the product.

iv) *Contribution margin:* Contribution margin is the difference between selling price per unit and the variable cost per unit. In other words:

Contribution Margin = Selling Price per unit – Variable cost per unit

Considering the figures given above contribution margin is Rs. 20 (i.e. Rs. 75 - Rs.55)

It may be noted that for calculating contribution margin, fixed cost is not considered.

After understanding the above concepts, we can move on to calculate break-even point (BEP) with the help of following formula:

$$\text{BEP (in units)} = \frac{\text{Fixed costs}}{\text{Contribution margin per unit}}$$

BEP (in units) = 40,000/20 = 2,000 units

BEP (in value) = 2,000 units * Selling price per unit i.e. Rs.75 = Rs. 1,50,000.

At the level of 2,000 units the manufacturer does not incur any loss nor earn any profit. This is verified as below:

Selling price of 2,000 units = 2,000*Rs.75 = Rs. 1,50,000

Variable cost of 2,000 units = 2,000*Rs.55 = Rs. 1,10,000

Fixed cost = Rs. 40,000

Total cost = (VC+FC) = Rs. 1,10,000 + Rs. 40,000 = Rs. 1,50,000.

The manufacturer does not earn or lose anything by selling 2,000 jam bottles because at this level both sales revenue (i.e. Rs. 1,50,000) and total cost (i.e. Rs. 1,50,000) are the same. Beyond this level he will start earning profit and below this level he will incur losses.

From controlling point of view the manufacturer has to understand whether he can operate above the level of break-even point. If he can do so in a shorter span, it is better for him. He must understand that the lower BEP denotes lesser risk.

6. Internal Audit

Internal audit is another effective tool of managerial control. It involves appraisal of operations i.e. weighing actual results in the light of planned results. It is a regular appraisal which is done by trained staff of internal auditors of the accounting, financial and other operations of a business.

It is concerned with long term business interest. It aims at evaluating the entire system of an organisation. It can be said to be a continuous, systematic and bias free study of total efficiency of the firm. It tries to measure and evaluate the effectiveness of all other control devices employed by the firm.

Internal audit is advantageous for the departmental managers as well. They get proper advice from the internal auditors on policies and plans of the firm. The auditors also suggest solutions to managerial problems.

The limiting factors for internal audit are two-fold – first, the business firm should be able to afford an internal audit and secondly, specialized persons should be available who can do a broad type of internal audit.

For making the internal audit successful, full support of subordinates is also required.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Does ratio analysis technique have an edge over Budgetary Control methods of appraising the performance of an enterprise? If so in what respects?

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2. Below is the performance measurement of Firm A and Firm B in terms of Gross Profit and Sales. You are required to make a comparison and state which of the firms has performed better.

	Firm A	**Firm B**
Gross profit (Rs.)	50,000	1,28,000
Sales (Rs.)	5,00,000	6,00,000

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3. Based on the following figures you are required to ascertain whether the performance of Firm A is improving or not:

	Year 1	Year II
NP ratio	12.21%	10.32%

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4. Which technique aims at a total evaluation of the entire system of an organisation?

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5. Give one word for the following.

   a) Certain costs which remain constant over a period of time.

      a) ……………………………………………………………………

   b) Costs which vary according to the level of production.

      b) ……………………………………………………………………

   c) A specialized person who evaluates various controlling techniques adopted by a firm.

      c) ……………………………………………………………………

   d) A monetary or physical plan meant for a specific future period.

      d) ……………………………………………………………………

   e) An effective controlling tool which establishes relationship between items of financial statement.

      a) ……………………………………………………………………

15.5 LET US SUM UP

Measurement of performance and its control is quite important because substantial benefits are realized by organizations which implement performance measurement programmes. Being a function of management, performance measurement makes the organization capable of taking sound decisions. Performance measures are generally expressed in terms of quantity. A performance measure is composed of a 'number' and a 'unit of measurement'. Single-dimensional and multi-dimensional are two types of units of which are generally used. An ideal unit of measurement should reflect needs of the customer and business; should be understandable, capable of being applied over a wide area and interpreted uniformly. Performance measurement is associated with controlling. Controlling is nothing else but to set standards, measure the performance, compare the performance with the standards set and take corrective measures if deviations are found. Some of the important tools and techniques of control are ratio analysis, cost analysis and control, credit control system, budgetary control, break-even analysis and internal audit.

15.6 KEY WORDS

Quality : The degree to which a product or service meets customer's requirements and expectations.

Control : The set of activities employed to detect and correct variation in order to restore a desired state of conformance with quality goals.

Remedial action : Measures taken to rectify conditions adverse to quality.

Unit of measurement : A quality feature that permits evaluation of that feature in numbers.

15.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. a) control
   b) unit of measure
   c) single
   d) quantity
   e) customer

2. a) False
   b) True
   c) False
   d) False
   e) False

3. i) Hours ii) Metres

Check Your Progress Exercise 2

1. It is based on feedback.

2. i) It is the last function of management.
   ii) It is a continuing process.

3. To plan the objectives of the firm.

Check Your Progress Exercise 3

1. **Hint:** i) Reduction in advertisement expenses by Rs. 50,000 in next 6 months.

   ii) Increasing the production by 5,000 units in next one month.

2. Standards will not be met leading to wastage of time, money and efforts as well as de-motivation for the concerned person.
3. To take remedial action quickly.

Check Your Progress Exercise 4

1. **Hint:** Ratio analysis focuses attention on relative figures which are actual. These figures are significantly related. Ratios help in judging solvency, profitability and liquidity of an organization. However, in case of Budgetary Control methods the budgets are prepared bases on estimated figures (future estimates) which are not actuals. Based on budgets solvency, profitability and liquidity of an organization can not be judged.
2. Firm B's performance is better because its GP ratio is high.
3. Firm A has not improved.
4. Internal audit
5. a) Fixed costs
   b) Variable costs
   c) Internal auditor
   d) Budget
   e) Ratio analysis

15.8 SOME USEFUL BOOKS

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15.9 ASSIGNMENTS

1. Why should a businessman measure his performance?
2. 'Planning and controlling are inter-dependent.' Justify.

3. What is control?

4. Explain the procedure of control.

5. Name the accounting ratios which can be calculated using the following financial factors as the basis:

   i) Turnover and average debtors
   ii) Turnover and net profit

6. Explain briefly any four benefits of measuring performance.

7. A businessman wants to apply budgetary control in his firm. He has already established the budgets for the current financial year. What according to you should he do next?

8. Why should a businessman analyse his costs?

9. What are performance measures? Explain its types briefly with examples.

10. Explain the features of controlling.

11. The following data relates to Evergreen Products Ltd.

Particulars	**March 31, 2003**	**March 31, 2004**
Sales	20,00,000	26,00,000
Cost of Goods Sold	15,00,000	21,20,000

The manager claims that he has worked more efficiently during 2004 because the sales and gross profit have increased and should get reward for his efficiency. The management of the company has sought your advice on the Manager's claim. Please advise.

(**Hint:** Calculate GP ratio)

12. What is internal audit?

13. Write the meaning and the formula of the following:

   i) Net Profit Ratio
   ii) Debtors' Turnover Ratio.

14. The following table gives actual and standard ratios for the year 2004-05 in case of Ganga Masale Di Hatti. Examine these ratios and suggest remedial action which the businessman should take.

Particulars	**Actual ratio**	**Standard ratio**
Current assets / current liabilities	6	2
Cash/current liabilities	5	1
Debtors/sales	9	12

(**Hint:** 1. The funds are lying idle and they can be invested.
2. Short term planning of funds should be improved by investing idle funds in income-yielding investments.
3. It indicates that the debtors are collected promptly.)

UNIT 16 MANAGING GROWTH

Structure

16.0 OBJECTIVES

After studying this unit, you should be able to:

- know about the growth of a business;
- understand the need of growth for a business;
- identify various measures of growth;
- comprehend the type of growth strategies used by business firms;
- understand the various stages of growth; and
- know the challenges faced by a businessman during the various stages of growth.

16.1 INTRODUCTION

What is Growth? What does this term mean? Haven't all of us grown from small children to adults? In fact, we find 'growth' all around us. Does not the small rose bud in our backyard grows and blooms into a beautiful flower? Does not a small mango sapling grow into a big mango tree? Does not a small kitten grow into a lovely cat? So, we find that growth is everywhere around us – whether it is a bud plant, an animal or a human being. In their growth process, human beings pass through the stages of infancy, childhood, adulthood and old age. Thus, in each and every case whether it is the question of survival of human beings or of a business, growth is a must. In the following Unit we will discuss the various aspects of growth of a business firm.

16.2 MEANING OF GROWTH AND ITS MEASURES

Meaning of Growth

The growth of a businessman is quite similar to that of a human being. It is a positive phenomenon. It is gradual. A businessman grows from the very initial stage – the day he starts the business and struggles hard to survive in the market – but slowly and gradually he finds himself in a stable and comfortable position. There are a large number of business firms, cottage industries etc.

which started in a small way and now have been transformed into big organisations, e.g. MDH, Amul Co-operatives, etc.

Measures of Growth

There are various parameters through which a businessman can come to know whether his business is growing or not. Some of the important measures of growth are as follows:

1. An increase in total net worth of the firm i.e. capital + reserves.
2. An increase in the size of total business of the firm.
3. An increase in the total number of employees.
4. An increase in the volume of output.
5. An increase in the monthly or yearly sales of the firm.

For better understanding, let's read the following Table 16.1:

Table 16.1: Growth in business

Particulars	**First year**	**Second year**
Revenue (Rs.)	1,00,000	5,00,000

Looking at the table it is clear that the sales revenue has increased by Rs. 4,00,000 in the second year i.e. the businessman has attained growth in his business.

16.3 NEED FOR GROWTH

A business man is motivated to grow for more than one reason. The various factors which drive him to grow are discussed in the following paragraphs.

1. *Forces of competition*

   A businessman needs to grow if he wants to survive in the market. Acute competition usually forces a businessman to grow in order to maintain his existence. In other words, a businessman has to be creative or he should innovate new things so that he is able to retain his present position.

2. *Economies of bulk*

   A businessman can avail certain benefits if he increases his volume of production. Large scale production provides several economies not only in the field of production but also in the areas of marketing, finance, management etc. Such economies of scale may include strong bargaining power, lower overheads, availability of finance at lower rates etc. The per unit cost of operation gets lowered due to the above mentioned economies.

3. *Better returns*

   The motive of the businessman to obtain more and more profits leads him to grow. He ensures growth of his organisation through continuous ploughing back part of profits instead of distribution of entire earnings .The size of the business thus gets expanded.

4. *Modern technology*

Business firms try to expand the size of the business in order to take advantage of modern or latest technology. Only large firms can take full advantage of hi- tech machines.

5. *Goodwill*

At times business firms prefer to expand in order to command power and respect. People take pride in owning business of large size. Business firms grow to achieve reputation. With reputation and size, power is not far behind. Big companies, no doubt, have more economic and social power compared to small business units.

6. *Personal factors*

Personal factors comprise individual organizational abilities, ambition etc. These factors also drive businessmen towards growth of their business firms. Certain businessmen may be highly ambitious or they may be endowed with special organizational skills. They may want to be independent too in respect of, say, marketing of raw materials or finished products.

7. *Trade cycles*

Trade cycles also influence the decision of growth of a business firm. During a period of boom businessman generally reaps high profits due to high production and high sales. The problem arises when at the time of depression economic activities come to the lowest level. The demand for the products goes down and so do the prices and profits. At this point of time when the businessmen are faced with the problem of closing down the business, they think of joining with other firms. They combine their businesses and grow.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Mention any two economies of scale which a businessman may avail in the process of expansion.

………………………………………………………………………………….

………………………………………………………………………………….

2. Name two measures of growth.

………………………………………………………………………………….

………………………………………………………………………………….

3. Name the need of growth in the following cases:

i) Mr. Khanna wants to make use of baking machine which has some added features of speed, volume etc.

i) ……………………………………………………………………….

ii) Mr. Ram Vilas has a desire to own and control a big business house.

ii) ……………………………………………………………………….

16.4 GROWTH STRATEGIES

A strategy is a well- planned course of action designed to achieve a specific objective. A growth strategy is a strategic plan meant to expand the operations of a business firm. A strategy which a firm may adopt will depend upon the fact whether the businessman wants to develop internally or externally.

Following are the main strategies which are usually followed by the businessmen for the growth of their enterprise.

A) **Internal Growth Strategies:** Internal growth strategy can be sub-divided into:

1. Expansion; and
2. Diversification

B) **External Growth Strategies:** External growth strategy can be sub-divided into:

1. Joint ventures; and
2. Mergers.

A) Internal Growth Strategies

Internal growth implies that the business firm expands its business without seeking help from other firms. Involvement of other firms is absent. The business firm grows from within. It is also called aggregative growth strategy.

A case study of Lizzat papad

Seven housewives in a small colony (Shankar Badi Lane, Mumbai) in 1957 sat together and discussed ways to use their spare time in a good and positive manner. They planned to make papads. They had their own doubts and apprehensions. Almost daily they discussed – 'How would we able to make papads?'; 'Who would buy from us?'; 'Would we have to go to each shop to sell the product, etc.?' Since their determination and will-power to venture into a new business was very strong, they persevered and began their business with a very modest amount. Today, as we all know they have a vast network. Their turnover, production, profits, employees, machines, net worth etc. all have increased. This is the story of growth of a business from within. Hundreds of other such organisations have also grown in a similar way.

Another case study of Everest masale

Some 40 years ago, Vadi Lal Shah, founder of "Everest Masale" started his career as a shopkeeper in a two hundred sq. ft. shop by manufacturing milk masala. Slowly and gradually his business started growing as he added some basic spices too. In 1968, he launched three blended spices – Everest Garam Masala, Kesri Milk Masala and Tea Masala. Today there are thirty four blends under the Everest brand name. For example, Pav Bhaji Masala, Subzi Masala, Sambhar Masala, Meat Masala, Chat Masala, etc.

The basic spices list also became longer and longer. It now includes turmeric powder, red chilli powder, coriander powder, black pepper powder etc.

At present, his business has grown to such an extent that approximately 1850 million packets of Everest Masale are sold each year. Within a span of forty years the company has captured a 30% market share in Indian food condiments segment. Its blends are available in over three lakhs outlets across a thousand towns and cities. This is another example of internal growth.

A firm may grow internally through:

i) Expansion
ii) Diversification

Let's discuss these ways of growth one by one.

i) Expansion

A businessman may start looking for opportunities for expansion as his business concern starts moving forward. Expansion is one way of internal growth. A firm may expand by increasing the sales, exploring new markets, developing new products and the like. It may plough back its profits for expansion or it may take loans or advances from financial institutions to increase its production capacity. The business unit will always retain its original character when it expands from within. Expansion may take the following forms:

a) Market Penetration
b) Market Development
c) Product Development

These forms of expansion are discussed below:

a) Market penetration

Under market penetration, a businessman tries to increase the sale of his existing products in the existing market. The businessman may try to increase the sales of his existing products in the same market. In other words, there is no change either in the firm's product or in its market. The entrepreneur generally tries to increase the sales by launching sales-promotion techniques e.g. Brook bond offered a glass bowl free with every 250 grams pack of tea to increase the sales of its product. Market penetration can also be achieved by selling goods at reduced prices.

b) Market development

Market development is different from market penetration. Under market development the businessman tries to explore new markets for existing products. A businessman dealing in rural areas may try to expand by catering to urban markets. A big manufacturer may on the other hand increase his sales by exploring rural areas as well, e.g. ready–to-eat food packs or fast food item being sold in rural areas. The businessman can also develop his market by crossing the boundaries of the country and start exporting the goods to the foreign traders or customers in foreign countries. Market development strategy is usually used by a businessman when existing markets are stagnant or when increase in market share is difficult because of powerful competitors.

c) *Product development*

Product development is yet another strategy adopted by a businessman who has a burning desire to grow and expand his business. Under this method, he plans either to develop a new product or modify the existing product. A product is modified by adding new features or value to it. The point to be noted is that creation of new product or modification of existing product is done for sale in the existing market. Development of new product is usually done to meet the changing needs and wants of the customers, to match new competitive advantage, to get the advantage of new technology etc.

Advantages of expansion

1. The businessman usually does not face any problem of funds as he may be a position to invest his previous years' profits and/or he may also borrow.
2. The businessman still remains at the top of the management ladder as there is no major change in the organisation structure.
3. The businessman may avail of economies of scale.
4. It opens up opportunities for competition.
5. The businessman is in a position to use the existing resources in a better way due to large scale production.

Disadvantages of expansion

1. Growth is slow and gradual. It is not instant.
2. The businessman may have paucity of funds if he does not have enough of his own resources to invest in various assets. In that case if he wants to carry out expansion programme he will have to knock at the doors of financial institutions for availing loans.
3. The businessman may hesitate to expand and increase the volume of output because he may not have that much strength to counter-act the moves of his competitors.
4. There may be limited scope of expansion in the present product market.

ii) Diversification

By now, we all know that growth is natural and gradual. A businessman in order to grow may increase the sale of existing products and may explore new markets for existing products or modify his products. These efforts will lead him to better utilisation of existing resources and more of profits. After some more time, he may reach a point where it is no longer possible to expand in the present product market. A better option for him would be to add new products or markets. This method of growth is known as diversification.

Diversification is nothing but trying new areas and new products i.e. entering new fields of business. For example, a tea manufacturer may diversify by entering sugar industry, or hotel industry.

Advantages of diversification

1. The businessman can utilise his resources in a better way.
2. He can balance the decline of sales in his present product.
3. There can be reduction of risk by developing a balanced portfolio of business.
4. Cash surplus of one business can be used to finance another business.
5. There is an increase in competitiveness of a firm.

B. External Growth Strategies

A business unit can grow by joining hands with another business firm. This is how a businessman grows externally. It is also called as integrative growth strategy.

A firm may grow externally through:

i) Joint Ventures
ii) Mergers

These external growth strategies are detailed below:

i) Joint ventures

Joint venture is another form of partnership between two business units. Here, two or more independent business firms join hands by contributing to total equity capital and by participating in the business operations together. It is usually for a specific purpose. It may also be called as temporary partnership meant for a limited purpose.

Advantages

1. When two business units join hands, it may result in the end of wasteful competition.
2. Reduction in production and marketing costs through more sales.
3. Risk is divided among the co-venturers.
4. Amount of investment is shared by two or more firms.
5. Better utilisation of resources.
6. Better control over market.
7. Economies of scale.

Disadvantages

1. Changes in organisation structure and management.
2. Lack of co-ordination among co-venturers.
3. Large amount of funds may be required.

ii) Mergers

Merger is another type of growth strategy. Integration/Combining of two or more firms into one is known as merger. It may be through take-over of one company by another or by creating a new company by full consolidation of two or more separate companies.

There may be a combining or merging of two or more firms engaged in the same production (e.g. Brooke Bond and Lipton merged together and formed a new company known as "Brooke Bond Lipton India Limited") or there may be a combination where combining units are complementary to each other.

In the process of merger two firms engaged in dissimilar lines may also combine. But this is not common.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Read the following extract given in the box and answer the questions given thereafter:

Hindustan Milk Food Manufacturers Limited was incorporated in 1958 to manufacture health food drinks. In the following decades the company underwent successive rounds of name changes following merger of associating companies. In December 2000, the associate company SmithKline Beecham Pic. merged globally with Glaxo Wellcome and formed Glaxo SmithKline Pic. In 2002, the brand created history by re-launching "Boost" with "power boosters™", a product completely different from any other health food drink. The company is working on products with further value addition, enlarging its presence in rural markets and developing a sizeable export plank.

a) Mention the names of the two companies which have been merged.

………………………………………………………………………….......

………………………………………………………………………….......

b) The name of the merged company is:

………………………………………………………………………….......

c) Name of the product which was re-launched is:

………………………………………………………………………….......

d) Which new market is the company trying to enter?

………………………………………………………………………......

e) Is the company trying to make its presence feel in the international market?

………………………………………………………………………......

f) Name the strategy adopted by the companies to grow.

………………………………………………………………………......

2. State True or False:

a) Expansion can be financed from the firm's own funds.
b) Growth is always fast.
c) Expansion involves additional risk.
d) Market penetration and market development are the same.
e) Development of new product is to meet the needs of the customers.

3. Mention any two advantages of diversification.

………………………………………………………………………......

………………………………………………………………………......

4. Fill in the blanks

a) ………………………. strategy aims at increasing sales of existing products in the current market.

b) ………………………. involves development of new product for existing market for new competitive advantage.

c) The ……………………………. strategy represents an effort to bring existing product into new market.

16.5 STAGES OF GROWTH AND CHALLENGES FACED BY THE ENTRPRENEURS

Every organisation follows some pattern of growth. Some businessmen may experience no growth at all and may have to leave the arena soon. On the other hand there may be a few who experience slow growth while there may be others who feel that their business is expanding at a very fast rate. Usually, at the commencement of the business, the rate of growth is slow. Gradually, as the business gains momentum the rate of growth quickens. The businessman at this time plans to expand the customer base and product line. As time passes, the entrepreneur may face sharp competition which may reduce the rate of growth. Market may become saturated as well. Some entrepreneurs may be forced to think that the period of decline is not far away and they would be ousted if certain revival measures are not taken. The businessmen are faced with new challenges and responsibilities as and when their venture transits from one phase to another.

In the following paragraphs let's now try to understand the different stages of growth and the various challenges which the businessman has to face at every stage.

Various Stages of Growth

Various stages of growth are as under:

1. Inception
2. Growth
3. Maturity
4. Decline

These stages of growth are discussed below:

1. Inception

The first stage starts with the discovery of an idea by the entrepreneur. He i.e. the entrepreneur is also known as the founder or the pioneer as he is the one who takes the lead. Here he is just like a sprinter who plans, trains, develops strategies and gets prepared both physically and mentally to run. Similarly, an entrepreneur does the spade work before starting the business. He may undertake the following kinds of studies during this period:

i) Study regarding the product

- Feasibility of the product.
- Designing of the product.
- Investigation regarding development costs, etc.

ii) Study of the market

- Who will buy the product?
- What can be the price?
- Will there be scope for the long term growth, etc.

iii) Study of finance

- Amount of personal savings.
- Availability of short term and long term loans, mortgage of property etc.
- Amount of seed capital required.

iv) Implementation

- Decide business location.
- Obtain licences from various agencies.
- Purchase machinery.
- Appoint employees.
- Sign agreements etc.

At this stage the sales are at the lowest; profits may or may not be earned; the firm may run out of cash; the rate of growth will be very slow and also it will be inconsistent, competition is uncertain. Usually a businessman offers only a single product at this stage and may cater only to a single market. The product is usually targeted to narrow market niches.

Many businesses come to an end during the stage of inception itself. In other words they do not reach the next stage of expansion at all. Can you think of the reasons? Well, it can be due to 'no planning' or 'wrong planning'; no feasibility plan made; lack of confidence; lack of vision; lack of business qualities; lack of capital; lack of market research, etc.

To avoid such failures, at the stage of inception, he should try to keep the price as low as possible, to cover the bare cost of the product. He should make a proper feasibility plan. He should also be very clear about the purpose of the project. He should try to build selective distribution system and try to build product awareness among early adopters and dealers. The psychological characteristics of the founder will largely determine how the venture will progress through this stage. The founder should have proper business plan. He should not rely on intuitions, he should be optimistic, energetic, and have the vision and foresight to wade through this initial stage which is full of problems and difficulties.

The businessman may also use heavy sales promotion schemes to attract trial.

2. *Growth*

A company can grow at a slow pace or at a very rapid rate. There may be business units which may have great potential for growth but the businessman himself may not be interested in further expansion. For example, a grocery-store owner may have no desire to expand beyond his capacity to own and manage a store personally.

In this stage the business can be transformed from a single-line enterprise operating in a limited market to a multi-line company penetrating new market. At this stage sales have a fast growth, profits are generally at the peak level, the competition is moderate, the product line is widened through innovation and development. Enterprises are enlarged. Due to expansion departments are created and authority delegated. There is decentralization.

To cope with this stage of growth the businessman requires effective leadership and vision. He should make well defined plans and should expand through strategic implementation of the plans. The business must be positioned to achieve long term objectives. He may launch new products or may enter new markets or may do both. He may have to provide better services, offer warranties, adopt penetrating price strategies, build intensive distribution system, and create interest in their product on a mass scale.

As the organisation expands the personal skills of the founder alone may not be sufficient. The organisation needs business related skills, functional expertise, marketing and operational skills etc. These decisions are beyond the scope of one person. Therefore, the personally managed firm may have to take the shape of professionally managed companies. The new activities will include marketing, cash flow management, inventory control, credit management, human resource development, logistics and distribution, management accounting etc. Decisions at this stage have to be based on systematic plans and through competitive evaluation and industry, market and the company. In a nutshell the businessman should be an able planner and he should be able to accept leadership roles which would be quite different from his role as a founder manager.

3. *Maturity*

Rapid growth cannot continue indefinitely. There will come a time when the market may become saturated. Competition is intensified; the businessman would be faced with marginally smaller incremental share of market. This is the period where maturity sets in.

The rate of growth is slowed down, capital becomes scarce, sales growth continues but at a diminished rate, profits start declining, many competitors enter the field. The weaker companies at this stage may fail or may be sold of. The businessman may reduce his product line or retreat from marginally profitable market. There may be a need to reduce the staff to streamline the distribution system and to withdraw from high risk market. The businessman may try to revise his business through innovative products. Re-positioning of product can also be tried. The company can utilise its resources towards research and development programmes.

4. *Decline*

If revival efforts are short-lived or ineffective the last stage i.e. decline sets in. Successful businessmen will not complete the life cycle because they will avoid decline. At this stage of decline, the sales will be very low and so the profits. There will be few new customers and no growth of business. The reasons for this decline can be many. The product of the businessman may have gone obsolete, the management may be inefficient. Ineffective leadership and lack of vision can be yet another reason for this disaster. For small business units, this phase is very difficult to handle due to very limited resources. Re-allocation of limited resources is the need of the hour. The businessman may have to take the help of professional managers who will identify the focal activity on which the future of the unit can be built. The stage of decline can be reversed through discovery of new uses of the product, appearance of new users, introduction of new features in a product etc. Decline may also occur if there is no successor to seen the show. The life of the venture is limited to the working life of its founder businessman. For example, a retail store or a small manufacturing firm may be sold or closed down for want of competent successors.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. Fill in the following table:

Variable/stages of growth	Inception	Growth	Maturity	Decline
Sales	Slow	-----	Slow	------
Product	-----	Multiple product	------	Obsolete product
Market	Single Market	----------	High potential market	----------
Profits	---------	Peak	-------	Low
Competitors	Few	Growing	-------	Declining

2. Choose the odd one out:

i) At the inception stage, the businessman will –

(a) design the product;
(b) investigate development cost;
(c) decide location of the plant;
(d) create various departments.

i) ……………………………………………………………………...

ii) At the growth stage, the businessman will –

(a) penetrate new market;
(b) delegate authority;
(c) obtain licences from various Government agencies;
(d) provide leadership to his employees.

ii) ……………………………………………………………………...

iii) At maturity stage the businessman will –

(a) face paucity of funds;
(b) reduce product line;
(c) encourage research and development programme;
(d) close down his business.

iii) ……………………………………………………………………...

iv) At decline stage the businessman will –

(a) streamline distribution system;
(b) have obsolete product;
(c) will have inefficient management;
(d) will have lack of vision.

iv) ……………………………………………………………………...

3. Match the following:

Stages	Challenges
i) Inception	A. To allocate limited resources.
ii) Growth	B. To reposition product line.
iii) Maturity	C. To plan organizational structure.
iv) Decline	D. To do break-even analysis.

16.6 LET US SUM UP

Growth is universal in nature. It is found everywhere around us. As human beings pass through the stages of infancy, childhood, adulthood and old age, similarly a business firm also passes through various stages of growth. Business growth is a natural and ongoing process. A businessman can judge the growth of his business through various parameters like increase in net worth; increase in total assets; increase in volume of output, etc. A businessman is motivated to grow so that he can survive in the market. He can avail several economies of large scale production like lower overheads, strong bargaining power, etc. He can earn more profits and can make use of modern technology if his business keeps on growing. The growth strategies which the businessman usually follows may be categorized as internal growth strategies and external growth strategies. The former includes expansion and diversification while the latter includes joint ventures and mergers. The business firm usually follows some pattern of growth. Some businessmen may experience no growth at all while others a slow growth. Still there may be others who may experience that their business is expanding at a very fast rate. Various stages of growth of a business firm include inception, growth, maturity and decline. It is not necessary that every business will experience decline stage. Much depends upon the vision and foresight of the persons managing the organisation.

16.7 KEY WORDS

Trade cycles : Business cycles i.e., a period of boom followed by a period of depression.

Seed capital : Amount required for product development, market research, initial operating expenses before sales begins.

Market niches : A carefully defined segment of a broader market.

Cash flow statement : A financial statement that accounts for actual cash received and spent in the course of doing business.

Feasibility plan : An initial written plan comprising all the elements of a good business plan with the objective of determining whether a new venture is expected to succeed.

Innovation : Transformation of creative ideas into useful application by combining resources in new or unusual ways to provide value to society for new or improved products, technique or service.

16.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. i) Strong bargaining power
   ii) Economy in freight

2. i) Increase in net worth of the firm
   ii) Increase in the volume of output

3. i) Modern technology
   ii) Personal factor

Check Your Progress Exercise 2

1. a) SmithKline Beecham Pic. And Glaxo Wellcome
   b) Glaxo SmithKline Pic.
   c) Boost
   d) Rural markets and export
   e) Yes
   f) Merger

2. a) T
   b) F
   c) T
   d) F
   e) T

3. i) Utilisation of resources in a better way.
   ii) Reduction in risk by developing a balanced portfolio of business.

4. a) Market penetration
   b) Product development
   c) Market development

Check Your Progress Exercise 3

1.

Variable/ stages of growth	Inception	Growth	Maturity	Decline
Sales	Slow	FAST	Slow	NEGATIVE
Product	SINGLE PRODUCT	Multiple product	INNOVATIVE PRODUCT	Obsolete product
Market	Single Market	MULTIPLE MARKET	High potential market	NO MARKET
Profits	NEGLIGIBLE	Peak	DECLINING	Low
Competitors	Few	Growing	MANY	Declining

2. i) (d)
   ii) (c)
   iii) (d)
   iv) (a)

3. i) D
   ii) C
   iii) B
   iv) A

16.9 SOME USEFUL BOOKS

1. David H. Holt (2002) Entrepreneurship – A New Venture Creation, Ed., Prentice Hall of India Private Limited, New Delhi

2. Gupta, C.B. and Khanka, S.S. (2004) Entrepreneurship and Small Business Management, Ed., Sultan Chand and Sons, New Delhi.

3. Varshney, R.L. and Gupta, S.L. (2000) Marketing Management (An Indian Perspective), Ed., Sultan Chand and Sons, New Delhi.

16.10 ASSIGNMENTS

1. Mention any two challenges which a businessman may face at the first two stages of growth.

2. Mention the various stages of growth.

3. Why does the businessman try to widen his product line through innovations while expanding?

4. Is decline of a business inevitable? Give two reasons to support your view.

5. What could be the various reasons for closure of a business firm:

   i) at inception stage;
   ii) at decline stage.

6. What is a joint venture? How is it different from mergers?

7. "Growth is slow and steady". Discuss.

8. Mention four advantages of diversification of business.

9. "Market development is different from market penetration". How?

10. A businessman is motivated to grow due to multiple factors. Discuss the various factors.

UNIT 17 INTERNATIONAL MARKETS: SCOPE FOR SMALL ENTERPRISES

Structure

17.0 OBJECTIVES

After studying this unit, you should be able to:

- understand the distinct characteristics associated with international marketing;
- get an insight into the target market;
- identify various business opportunities, offered by the international markets;
- describe the various routes through which international markets may be accessed;
- understand the various export incentives; and
- comprehend export pricing and export documentation.

17.1 INTRODUCTION

When a businessman crosses national boundaries for purchase and /or sale of goods and services, he enters international markets. Purchase of goods from international markets is called 'import' and sale of goods thereto is called 'export'.

All the activities, which take place in the domestic market, are also associated with international marketing. Thus, a businessman operating in international market shall have to identify correctly, assess and interpret the needs of the buyers in the foreign country and make marketing effort to satisfy those needs. However, there are certain distinct characteristics, which are associated with the international marketing only. These are:

Rules and regulations framed by the Government: A businessman desiring to enter the international market has to follow complex formalities relating to customs, foreign exchange etc. He should have full knowledge of rules and regulations governing foreign trade. Documentation part of foreign trade is much more complicated. All these formalities require expense of time and money.

Different languages and customs: There may be some communication barriers because each nation has its own language and customs. Though English is the common language used yet in certain countries people use their own language.

Transit risk: Trading in international market implies that the goods have to undergo long transportation route before they reach the destination. An all-proof packing is a must for the exportable goods. Modes of transport used, in the case of foreign trade is land air or sea. In these modes of transport transit risk is always on the higher side. The goods must be insured before despatch.

Problem of foreign exchange: The currency circulating in the importing and the exporting country is not the same. The currency of one country is considered as a commodity in the other country. Thus, in the case of foreign trade there always remains the problem of exchange of currency. There is a risk associated with the exchange rates, which are always fluctuating. Settlement of accounts between the exporter and the importer may create certain difficulties.

Creditworthiness of the customers: Due to the distances involved the exporter and the importer hardly meet physically. In the absence of any meeting exporter has to depend upon the references for ascertaining the creditworthiness of his customers. The exporter is not certain whether he has obtained the correct picture of his customer.

Blocking of capital: The capital of the businessman remains blocked for comparatively longer period of time because payments are not realized immediately. A number of intermediaries are involved in the case of foreign trade. This results in longer time gap between dispatching of goods and ultimate realisation of payments from the importers.

17.2 KNOWLEDGE ABOUT THE MARKET

Knowledge of the product in which the businessman wants to deal is important but at the same time knowing the target market (in this case the foreign market) is equally important. It has been observed that the most successful exporters remain in constant touch with the market.

Defining the Market

A businessman has to define the geographic location of his potential market. It may be just across the border i.e. neighbourhood or a far off city or a particular region or the whole country. If the businessman knows his market clearly he may be in a position to focus his marketing efforts. Following points need attention of a prospective exporter:

- Potential customers of the product and why they need the product.
- In which way the product is now to the market or different from the product available to it.
- In which way the product is more desirable.
- What are the chances that the product will be accepted or rejected in the prospective market?
- Prepare a list of prospective market areas. These should be the areas where the exporter thinks that his sales programme for the product may find support.

- A testing of prospective market areas may be done with a view to determine where marketing efforts will be more productive.

Initially, it will be more appropriate to deal in a small, geographic locality and thereafter extend the market to keep the cost of operations reasonable.

What Constitutes the Prospective Market

The businessman should find out what? before exporting his product the type of customer and the business. For example:

- Does the target customer belong to a particular age, social or economic group?
- Is the target customer more interested in quality and durability of the product?
- Is the target customer already buying a similar product, which is offered for sale or he is to be educated regarding the uses of product?
- Which of the needs of the target customer will be fulfilled by the product offered for sale?
- Is the target customer likely to haggle/bargain?

Keeping Track of Movements of Exportable Product

The businessman should know beforehand as to when demand for his product arises in the international market. Knowledge of seasonality of demand is very important. If the businessman knows the timing when his product is needed, say near a particular festival time, he should schedule his operations backwards from that date so that supplies are made available well before that festival. The following movements of merchandise may take several weeks (and even months) for completion:

- Movement of goods from importer's warehouse to retailer's warehouse in the importing country.
- Clearance of goods through foreign customs.
- Transporting of goods from the point of manufacture to the port of export.
- Manufacturing time required for producing the goods.
- Preliminary research, planning etc.

All the above tasks may take much longer time than expected and therefore a track of movement of merchandise must be kept.

Conducting Market Research

The businessman should conduct market research in one form or the other on a continuous basis. Good business planning is not possible if no market research is conducted on regular basis. At present it is a buyers' market and not a sellers' market. There is always a need to secure information on the needs and preferences of consumers. It must be the endeavour of the exporter constantly to analyse what is happening in the market place.

Contacting Potential Customers

The businessman needs to know his potential customers. If he knows his market and the customers well, he will be in a position to offer what they need rather than what he wants to sell. In other words a rapport with customers is a must. He may ask his potential customers in the foreign market:

- What is your requirement?
- What is selling well? What features will make for good sales?
- What price would the market bear?
- What terms of sale would you require?

The exporter should find out the stores and businesses they are already interested in goods from his country or are dealing with products in the same line on his intended exports as his potential customers one likely to be found among them.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Fill in the blanks:

   i) Purchase of goods from international markets is called ------------.

   ii) Sale of goods to international markets is called ---------------------.

   iii) Modes of transport used for foreign trade include ---------------- and ----------------------.

   iv) ------------------- should be conducted on regular basis for good business planning.

   v) In foreign trade capital invested remains blocked for comparatively longer period of time due to number of ---------------- involved.

2. Mention two distinct characteristics of foreign trade.

   ……………………………………………………………………………………

   ……………………………………………………………………………………

3. Why does an exporter need to know his potential customers?

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

17.3 OPPORTUNITIES OFFERED BY THE INTERNATIONAL MARKETS

International markets offer a number of opportunities to a businessman. They are listed as below:

i) Scope for bulk sales

Usually export orders are much larger than those emerging from the domestic markets. Sometimes a single export order may far exceed the total supply made by the firm in a year in the domestic market. The businessman has, thus, the opportunity to go for bulk sales.

ii) *Scope for full utilisation of installed capacity*

Sometimes it may happen that the businessman has got the installed capacity but the same cannot be utilised fully because there is no sufficient demand in the domestic market. Export business provides a suitable opportunity to use the installed capacity to its full extent.

iii) *Scope to overcome recession in the domestic market*

The businessman may face recession in the domestic market for his product. To overcome recession international markets provide a golden opportunity. Recession serves as a stimulus to various export opportunities. The businessman can venture to enter the international markets and create a place for his products.

iv) *Scope to overcome legal restrictions in the domestic market*

Sometimes it may happen that the Government might impose certain restrictions in the domestic market on sale of certain products or on the further growth of particular firms. However, this problem may be sorted out by resorting to exports i.e. accessing international markets. Even the exports may help the businessman to earn export incentives from the Government.

v) *Scope for technological advancement*

A businessman opting for international market might be enabled to pick up new product ideas and to add to the existing product line. Exports provide the chance to go for technological advancement, which may help the businessman to improve his product. Improvement in products will help in reducing costs and also discovering new uses of the product. This can even help in capturing more share of domestic market.

vi) *Scope for diversifying business risks*

Entry into the international market provides an opportunity to the exporter to diversify his risks. At times, domestic market may show downward fluctuation in sales resulting in low turnover and profits. This may be offset if the businessman opts for exports and targets international market to boost his sales. This is nothing but geographical diversification. The businessman can attain growth in his business by adopting this kind of diversification because a single market may not give adequate profits.

vii) *Scope for increase in production*

Survival needs of a business require increase in production. The firm will go for increased production if there is scope for absorption of its product. International markets present an opportunity for absorbing increased production if it is up to the international standards. The businessman may opt for markets in developed and developing nations for supplying his product. Production at large scale helps the firm to derive economies of scale and reduce the cost of production.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State True or False against each:

   i) There is no scope for bulk sales in case of foreign trade.

   ii) Export business helps in utilizing installed capacity to its full extent.

   iii) Recession in the domestic market does not serve as a stimulus to various export opportunities.

   iv) International markets enable a businessman to pick up new product ideas.

   v) Risks can be diversified by entering international markets.

2. Mention two opportunities available if the businessman enters international markets.

   i) ………………………………………………………………………...

   ii) ………………………………………………………………………...

3. "International markets present an opportunity for absorbing increased production". Comment.

   ……………………………………………………………………….........

   ……………………………………………………………………….........

   ……………………………………………………………………….........

17.4 HOW TO ENTER INTERNATIONAL MARKETS?

A businessman can enter international markets by following any of the following routes mentioned below:

I. Indirect Route
II. Direct Route
III. Other Miscellaneous Routes

Let's now discuss these routes in detail.

I. Indirect Route

In this case the businessman does not enter international markets on his own. He takes the help of merchant exporters for exporting his products. These merchant exporters are usually recognised as star export houses (categorised as one star export house, two star export house, three star export house, four star export house and five star export house – in terms of Foreign Trade Policy 2004-2009).

Export houses are also interested in promoting the exports of goods originating from units in small-scale industry, Tiny sector, cottage industry sector and units registered with KVICs or KVIBs. This is so because, for being recognised as star export houses, these merchant exporters are required to achieve certain export performance. In case they export goods originating from above type of units, they are entitled for double weightage of such exports in calculating their export performance. Further export of agro-products also entitles them to double weightage.

- *Benefits of Exporting Products through Star Export Houses*

  i) *Gain from wide knowledge and experience:* These merchant exporters have wide knowledge and experience about the products, which have an export market. Similarly, they know the international markets, trends prevailing there much better.

  ii) *Availability of finance:* The manufacturers can obtain pre-shipment finance from the export houses as in deserving cases they extend financing facility to their supporting manufacturers. Similarly, the manufacturer can obtain pre-shipment and post -shipment finance from banks on the guarantee of merchant bankers.

  iii) *Less financial risk:* There is less financial risk involved while exporting goods through export houses because generally they (i.e. export houses) make payment to the businessman as soon as he delivers the exportable goods to them.

  iv) *Invaluable advice regarding characteristics of international markets:* Merchant exporters can advise the manufacturers regarding production pattern, packing standards, quality requirements and other important characteristics of international markets. Based on the advice, the manufacturer can bring out a product acceptable in the overseas market.

  v) *Dealers' network:* Most of the merchant exporters have a dealers' network and sales organisations operating in many international markets. Through these organisations and the network they can provide exporting opportunities to the businessman.

  vi) *Valuable guidance regarding product development:* Merchant exporters can provide valuable guidance to the businessman with regard to product development so that exportable products match the international standards. At times they may even give samples of exportable products.

  vii) *Better terms for shipping and insurance:* Shipping and insurance play a major role in exports. The merchant exporters can secure better terms from shipping and insurance companies as compared to the businessman if he wants to act on his own. This is so because the merchant exporters have their own arrangements with these companies and therefore they are in a position to obtain better deals for their clients. At times, merchant exporters combine several shipments from various firms and the goods are shipped that way. This helps in reducing transporting charges considerably.

  viii) *Professional handling of export documentation:* In case of exports, lot of shipping and documentation work is involved, which the merchant exporters can handle more professionally.

II. Direct Route

Export of goods through merchant exporters may not always be beneficial. The main drawback is that the businessman does not get the chance to create goodwill for his our product and brand name. Also he gets less net return on sales to allow for the profit of merchant exporter. He is not recognised in the international market though his product is exported. You will note that success in the international market as exporter may help him in boosting his image in the domestic market also. Keeping these facts in view the businessman may opt for direct exporting. In this respect he may take the following steps:

i) *Try to establish contacts with big departmental stores*

The businessman should try to establish contacts with the big departmental stores in the developed as well as developing countries. Departmental stores keep a variety of products like grocery items, ready-made garments, electronic gadgets, leather goods, jewellery items etc. The key persons to be contacted there may be few. If the product to be exported is of good quality, the businessman may use his personal selling techniques and be in a position to convince one or two such departmental stores to purchase his product. If he succeeds in his endeavour and his product finds way into such departmental stores and the sales of that product at that end picks up it will boost his performance and reputation. There are chances that other departmental stores may also come to know of that product and may place orders for supply. Thus, he will get more and more business.

ii) *Try to establish contacts with institutional buyers*

In every country there are institutional buyers like hospitals, government establishments, hotels, educational institutions etc. In every such institution there is a particular department or key person who purchase the supplies. Here, the businessman has to use his personal selling techniques and thereby establish contacts and persuade the persons concerned to purchase his product. If he succeeds he may secure large export business.

iii) *Direct exporting through co-operative societies*

Forming of co-operative societies by persons having common interest is quite usual in various countries. The members of these co-operatives try to secure better terms for purchasing their requirements. Here also, the key persons to be contacted may be few. In case the businessman is good at personal selling with additional requirement that he produces a qualitative product, he may hope to secure large export orders.

iv) *Overseas sales agents*

Overseas sales agents play an important role in establishing contacts with the importers. They are always near the international markets. A sales agent may be a commission agent or a distributor. In case of commission agents, they secure export orders for the exporters. For their services, they receive an agreed rate of commission from the exporters. In case of distributors, they purchase the exportable products from the exporters. Thereafter, they sell the products on their own through the sale outlets owned by them. Overseas sales agents are very useful to the exporters inasmuch as they provide latest information for adopting right market strategy and guide the exporters in choosing a proper channel of distribution.

Note: It is advisable for a small-scale entrepreneur to undertake export through merchant exporters (i.e. indirect exporting) initially. After gathering enough experience regarding international markets, packaging of exportable products, export documentation, dealing with shipping companies etc. he could go for direct exporting.

III. Other Miscellaneous Routes

Besides indirect and direct exporting there are certain other options available through which entry into international markets may be made. These are stated as below:

a) *Opening a branch office or subsidiary abroad:* The businessman may take steps to open a branch office in a foreign country or even subsidiary at that end. The work to be undertaken there may include processing of the product including assembly and packaging. In the course of time, as the business develops, even complete manufacturing may also be undertaken.

b) *Going for joint ventures:* This is another option available and the businessman may go for joint ventures in foreign countries. Through the joint ventures he may undertake marketing of the product in that country. Manufacturing activities may also be undertaken depending upon the purpose for which the joint venture has been formed. In India a number of joint ventures where foreigners are involved, are operating successfully.

c) *Providing consultancy services:* Another way of entering international markets is to provide consultancy services. A person having expertise in agricultural activities may offer expert advice to the foreigners in increasing the agricultural output. Consultancy services can be provided in other fields of business also. Persons providing consultancy services are known as consultants.

d) *Technology transfer:* The businessman may enter into contract with the foreigners for supply of technology. A franchising agreement may be entered into in this respect. Similarly patents, trademark etc. of the exporting firm may also be used by the overseas buyers.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Name the following:

i) a merchant exporter who helps the businessman in exporting his products.

ii) a person who works on commission basis in the international markets.

iii) a person offering consultancy services to the foreigners.

iv) a person who purchases goods from the exporters and sells them on his own in the international market.

v) A store which keeps a variety of products and which can be contacted by the exporter.

2. Explain the other miscellaneous routes of entering into international markets.

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17.5 EXPORT CONCESSIONS, INCENTIVES AND PROMOTIONAL MEASURES

In India, the Government has encouraged exports to a considerable extent. A number of export concessions and incentives are available to the exporters – no matter whether they are working on a small scale or large scale. Till 2004, Government had operated EXIM Policy for promotion of exports. Now it is Foreign Trade Policy 2004-2009, which will provide export promotion measures. In the following paragraphs we will study about these concessions, incentives and export promotional measures.

i) Export Finance

Banks have been authorised to provide export finance to exporters at concessional rates. Finance is needed both for the manufacture of exportable goods and after the shipment of the goods. These are termed as pre-shipment finance or packing credit, and post shipment finance. Under pre-shipment finance facility, the exporter obtains finance for purchase, processing, manufacturing, or packing of goods for export purposes. Under post-shipment finance facility, the exporter obtains finance to cover the time to receive payment after the shipment of goods.

ii) Duty Exemption/Remission Schemes

These schemes facilitate import of goods for export production. *Duty exemption schemes* enable duty free import of inputs required for export production. The process starts by issue of an advance licence for duty free import of inputs. The advance licence is issued subject to the actual user condition. Therefore, advance licence and material imported thereunder shall not be transferable even after completion of export obligation. The licence can be issued for physical exports, intermediate supplies and deemed exports.

A *duty remission scheme* enables post export replenishment / remission of duty on inputs used in the export product. These schemes consist of Duty Free Replenishment Certificate (DFRC) Scheme and Duty Entitlement Pass Book (DEPB) Scheme. DFRC permits duty free replenishment of inputs used in the export product. DEPB allows drawback of import charges on inputs used in the export product.

iii) Export Promotion Capital Goods (EPCG) Scheme

Under this scheme import of capital goods is permitted. These capital goods are to be used for export production. New capital goods including computer software systems can be imported under EPCG scheme. The import is permitted at a concessional customs duty rate of 5%. However, export obligation equivalent to 8 times of customs duty saved on capital goods imported under the EPCG scheme shall be fulfilled over a period of 8 years. The period for fulfilling export obligation shall be increased to 12 years if the duty saved is Rs. 100 crores or more. For exports of agricultural products and their value added variants, import of capital goods would be allowed at 0% duty.

iv) *Duty Drawback (DDB) Scheme*

For the production of export goods raw materials and components are used on which excise duty/customs duty is paid. Under *Duty Drawback Scheme* excise and customs duties paid on raw materials and components used for producing export goods are refunded to the exporters once the exports materialise.

v) *Deemed Exports*

In case of deemed exports, goods supplied or sold do not leave the country. This is possible when the goods are supplied to some particular establishments like units located in EPZ, 100% EOUs, projects funded by United Nations Agencies or multilateral or bilateral agencies, power projects and refineries, etc. in India. Payment for these supplies is received either in Indian rupees or free foreign exchange. Deemed exports are eligible for following benefits:

a) Advance licence for intermediate supplies/deemed exports/DFRC/ DFRC for intermediate supplies.
b) Deemed export drawback.
c) Exemption / refund of terminal excise duty.

vi) *Market Development Assistance (MDA)*

Under MDA scheme, assistance is provided to the exporter for marketing his products in the international markets. You know that export marketing requires heavy investments. Exporters on their own may not be in a position to market the products. To help them out in marketing of export products, MDA has been devised. As per the revised Guidelines effective from April, 2004 assistance under MDA is available to exporters with annual export turnover up to Rs. 5 crores. The marketing development assistance is provided for the following purposes:

a) Individual sales-cum-study tours/trade delegations abroad.
b) Individual participation in trade fairs, exhibitions and buyers-cum-sellers meets abroad or in India.
c) For conducting Export promotion seminars.
d) Publicity and advertisement.
e) Other specified activities.

vii) *Taxation Relief*

For promoting exports income tax exemption is available. However, the income tax exemption scheme is going to be phased out over a period of five years by 2004-05. It is provided that the scheme shall remain operational for the units located in EPZs and in case of 100% EOUs. As regards sales tax, the same is not to be levied in case of export sales. Goods meant for export can be purchased without payment of sales tax against issue of Form H. Further excise duty is not leviable on and if paid is refunded to the exporters.

viii)Export Processing Zones (EPZ)

With a view to provide an internationally competitive duty free environment for production of exportable goods, EPZs have been set up. Units located in EPZs get infrastructural facilities for manufacturing products at lower cost. They need not obtain import licence for importing capital goods, raw materials etc. Excise duty is exempted on capital goods and raw materials purchased from the domestic market.

ix) 100% Export Oriented Units (100% EOUs)

A businessman can set up these types of units anywhere in the country. 100% EOUs are required to export their entire production except some permitted portion, which can be sold in the domestic market. Similar facilities which are available to units located in EPZs are also available to 100% EOUs. An EOU engaged in agriculture, floriculture or horticulture may be permitted to remove specified goods in connection with its activities for use outside the bonded area.

x) Special Agricultural Produce Scheme (Vishesh Krishi Upaj Yojana)

This Scheme has been announced in the Foreign Trade Policy 2004-2009. The objective of the Scheme is to promote export of fruits, vegetables, flowers, minor forest produce, and their value added products. Exporters of such products shall be entitled for Duty Credit Scrip equivalent to 5% of the FOB value of exports for each licensing year commencing from 1st April 2004. The exporters can freely transfer the scrip and the items imported against it. Further, the Duty Credit may be used for import of inputs or goods including capital goods.

Check Your Progress Exercise 4

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Write full forms of the following abbreviated schemes:

   i) DEPB Scheme ---

   ii) DFRC Scheme ---

   iii) EPCG Scheme ---

   iv) MDA Scheme ---

   v) DDB Scheme ---

2. Following paragraph, which relates to 'Export Finance', contains certain blanks. You are required to fill in the blanks with appropriate words:

   'Banks have been authorised to provide export finance to exporters at ------------- rates. Finance is needed both for the manufacture of ------------ goods and after the shipment of the goods. These are termed as -------------- finance or packing credit, and ------------- finance. Under the facility, the exporter obtains finance for purchase, ------------, manufacturing, or --------- of goods for export purposes. Under post-shipment finance facility, the exporter obtains finance for the purpose that it may take sometime to receive --------------- after the shipment of goods.'

17.6 EXPORT PRICING AND EXPORT DOCUMENTS

Export Pricing

Export pricing is the most important factor, which a businessman must consider for success in the international markets. There are some specific issues associated with export pricing which are not present in the domestic pricing of a product. These are as under:

i) Currency for export pricing

In India, the businessman can quote the price of his product in rupees but when he goes into the international market there arises a question – in which currency he should quote the price. Exchange rate fluctuations can increase or decrease the export profits to a significant extent. A stable currency should be considered for export pricing.

ii) Consideration of inflation

Every country in the world is in the grip of inflation. Prices of the products are affected by the inflationary conditions. Therefore, to counteract the inflation, pricing policy should be so designed that it takes into account the measures, which help in decreasing the impact of inflation. If the businessman faces high inflation rates, he may follow NIFO (Next in First Out) system.

iii) Quoting of export price (Price quotations)

In case of international marketing there are many ways in which export price may be quoted. These are as under:

- *Loco price:* Loco price, also known as ex-factory price includes the cost of production and the normal profit margin. In case of this type of quotation the foreign importer has to collect the goods from the seller's warehouse. The other expenses incurred for taking the goods to importer's place are to be borne by the importer.
- *F.O.R. (Free on Rail):* In this type of quotation, the exporter quotes the export price, which includes the cost of goods, profit margin and the cost of carrying the goods to the railway station and loading them.
- *F.A.S. (Free along side ship):* In this type of quotation, the exporter quotes the export price, which includes the cost of goods, profit margin, cost of carrying the goods to the railway station and loading them, and charges for placing the goods near the ship.
- *F.O.B. (Free on Board):* In this type of quotation, the exporter quotes the export price, which includes the cost of goods, profit margin, cost of carrying the goods to the railway station and loading them in the wagons, and charges for loading the goods into the ship.
- *C. & F (Cost & Freight):* This type of price quotation includes the F.O.B. price and the freight payable to the shipping company for transporting the goods to the importer's country.
- *C.I.F. (Cost Insurance & Freight):* In this type of quotation, the exporter quotes the export price, which includes C&F price and the premium paid for marine insurance.

- *Ex-ship price:* In this type of quotation, the exporter quotes the export price, which includes all the expenses until the ship arrives at the port of destination.
- *Landed price:* In this type of quotation, the exporter quotes the export price, which includes ex-ship price and also the cost of unloading the goods from the ship.
- *FRANCO:* This type of price quotation includes all the expenses for delivering the goods at the warehouse of the importer.

Export Documents

There are certain principal export documents, which are required for transferring ownership of the goods from the exporter to the importer. There are certain other documents, termed as auxiliary export documents, which are required for the preparation of principal export documents. These export documents are stated below:

Principal export documents

i) Commercial Invoice

ii) Packing List

iii) Bill of Lading

iv) Certificate of Inspection

v) Letter of Credit

vi) Marine Insurance Policy

vii) Certificate of Origin

viii) Bill of Exchange

Auxiliary export documents

i) Proforma Invoice

ii) Intimation for Inspection

iii) Shipping Instructions

iv) Insurance Declaration

v) Shipping Order

vi) Mate's Receipt

vii) Application for Certificate of Origin

viii) Letter to the Bank for negotiation or collection of documents

Check Your Progress Exercise 5

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. The two factors, which influence export pricing, are as under:

   i) ……………………………………………………………………………

   ii) ……………………………………………………………………………

2. What are the full forms of following price quotations:

   i) F.O.R. --

   ii) F.A.S.--

3. What is LOCO Price? How is it different from FRANCO?

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………

17.7 LET US SUM UP

Doing business after crossing national boundaries means entering into international markets. Purchase of goods from international markets is called ‘import’ and sale of goods thereto is called ‘export’. Before going for exports the businessman needs to know the target market. His should understand his customers, what type of product they need, whether the product he is offering fits into the category, which is in demand and so on. He is required to keep a track of the movements of his product, which he desires to export so that it is placed in the target international market at the right time. In this connection he should schedule operations backwards. A market research on regular basis is a must because at present it is a buyers’ market and not a sellers’ market. The businessman should remain in constant contact with his customers. International markets offer a number of opportunities like scope for bulk sales, full utilisation of installed capacity, overcoming of any legal restrictions or recession in the domestic market, diversification of business risks, increase in production etc. International markets may be approached either through indirect exporting or direct exporting but it is always better if a small entrepreneur initially adopts the route of merchant exporters for exporting his goods. Other routes of entering international markets include opening a branch office or subsidiary in the foreign country, going for joint ventures with foreign nationals providing consultancy services and transfer of technology. In India, a number of concessions, incentives and promotional measures are available for boosting exports. They include availability of export finance at lower rates of interest, duty exemption/remission schemes, EPCG scheme for import of capital goods, duty drawback scheme, deemed exports, market development assistance scheme, taxation relief, duty credit scrip to the exporters of horticulture produce, etc. Export pricing should be done keeping in view the specific issues associated with it. Depending upon the agreement reached between the exporter and the importer, export price quotation may be loco price, F.O.R., F.A.S., F.O.B., C. & F., C.I.F., ex-ship price, landed price or FRANCO. In the export of goods a number of documents are involved which may be categorised as principal export documents and auxiliary export documents.

17.8 KEY WORDS

Joint venture : A kind of business partnership between two firms to achieve a common purpose.

Pre-shipment finance : Finance availed from banks for manufacturing/procurement of exportable goods.

Post-shipment finance: Finance availed from banks before realisation of export proceeds.

Subsidiary : A company whose 51% or more share capital is held by another company.

17.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. i) Import ii) Export iii) Sea, Air
   iv) Market research; v) Intermediaries

2. i) Applicability of rules and regulations connected with foreign trade.
   ii) Applicability of foreign exchange laws.

3. **Hint:** So that the exporter is in a position to offer what his potential customers need.

Check Your Progress Exercise 2

1. i) False ii) True iii) False
   iv) True v) True

2. i) Scope for bulk sales
   ii) Scope to overcome recession in the domestic market.

3. Yes. International markets present an opportunity for absorbing increased production. To achieve this, the businessman may opt for markets in developed and developing nations for supplying his product.

Check Your Progress Exercise 3

1. i) Star export house ii) Commission agent
   iii) Consultant iv) Distributor
   v) Departmental store

2. Opening a branch office; Entering into Joint Ventures: through technology transfer.

Check Your Progress Exercise 4

1. i) Duty Entitlement Pass Book Scheme.
   ii) Duty Free Replenishment Certificate Scheme
   iii) Export Promotion Capital Goods Scheme
   iv) Market Development Assistance Scheme
   v) Duty Drawback Scheme

2. concessional; exportable; pre-shipment; post shipment;
   processing; packing; payment

Check Your Progress Exercise 5

1. i) Currency ii) Inflation
2. i) Free on rail ii) Free along side ship
3. Loco price includes the cost of production and the normal profit margin whereas FRANCO price includes all the expenses for delivering the goods at the warehouse of the importer.

17.10 SOME USEFUL BOOKS

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5. Varshney, R.L. and Bhattacharya, B. (2000) International Marketing Management – An Indian Perspective, Ed., Sultan Chand and Sons, New Delhi.
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17.11 ASSIGNMENTS

1. What is foreign trade?
2. Mention any three benefits of export of goods through indirect route.
3. Explain the distinct characteristics associated with the international marketing.
4. Enumerate the areas where an exporter is required to focus his attention while defining his potential market.
5. International markets offer a number of opportunities to a businessman. How?
6. Name the various types of star export houses.
7. ‘Export of goods through merchant exporters may not always be beneficial.’ Why? Suggest any two ways through which an exporter may overcome this problem.

8. Write short notes on:

   i) Duty exemption / remission schemes.
   ii) Market development assistance.

9. Explain briefly the following export price quotations:

   i) F.O.B. price
   ii) C.I.F.
   iii) FRANCO

10. State any five documents used in the export transactions.