UNIT –1 INTRODUCTION TO FOOD SCIENCE AND SIMPLE SUGARS

Structure

1.1 INTRODUCTION

This first unit introduces the concept, scope and importance of food science and technology as a discipline. It further presents a detailed discussion on carbohydrates in the diet, their classification, functional properties and their uses in foods.

Objectives

After studying this unit you will be able to:

- appreciate the discipline of food science and the modern developments in this subject area
- classify carbohydrates
- discuss the functionality of sugars in our food
- enumerate the different sweeteners and their functions

1.2 INTRODUCTION TO FOOD SCIENCE AS A DISCIPLINE AND MODERN DEVELOPMENTS

As an undergraduate student you may have taken a course in food science and technology. Do you recall, what did the study of food science and/or food technology entailed? In this course, we begin our study by first defining what food science and technology is.

Food Science is a discipline in which the biological and physical sciences and engineering are used to study the nature of foods, the causes of their deterioration, and the principles underlying food processing. It deals with acquisition of new knowledge to elucidate the course of reactions or changes occurring in foods, whether natural or induced by handling procedures.

Food Technology, on the other hand, is application of food science to the selection, preservation, processing, packaging, distribution and use of safe, nutritious and wholesome food. It is application of the principles and facts of science, engineering, and mathematics to the processing, preservation, storage and utilization of foods.

If you look at the definitions carefully, you would realise that food science and technology are inextricably linked. Because of their inter-linkages and commonality, you would find that they are usually treated as one field of study in many universities.

Next, let us move on, to study the importance of this discipline in general and specific to dietetics and food service management.

Paying attention to food science and technology - subject scope

Food science and technology has developed as a discipline to systematically organize and link various kinds of knowledge which are necessary to inform human activity in handling, processing, distribution and marketing of food. This also includes application of science and technology to the processing, preservation, packaging, distribution and utilization of foods and food products. The objective of the discipline is to develop a basic scientific understanding of foods and food processing as determined through biochemistry, chemistry, microbiology, physics and other sciences. Food science and technology is the key to the conversion of raw agricultural materials into a wide variety of properly processed and preserved foods, thus contributing to the well being, economy, standard of living and progress of humanity.

Food science, you would realize, actually draws on research and applies principles and practices from a broad spectrum of basic and applied sciences including biology (botany, bacteriology, microbiology, mycology); chemistry (biochemistry, physical, analytical, and organic chemistry); physics (rheology, thermodynamics, cryogenics, radiophysics, ultrasonics); nutrition; psychology (sensory behaviors); medicine (metabolism, toxicology, health and diseases) and economics.

Food technology applies the principles and concepts of engineering to problems of food handling and processing and studies interrelationships between the properties of materials and changing the methods of handling and manufacturing them.

The food business and food technology are practically inseparable. The food business may be characterized as: vulnerable to spoilage, high volume, low margin, multiple products, transportation intensive and end user marketing intensive. Since World War II, the value added part of the food industry has steadily increased and in 1980, it surpassed agriculture's contribution. There is a great emphasis on speed and efficiency in production and on optimization of the food system from production through consumption. It has even been predicted that nutrient delivery packages customized for particular situations, will be developed to take the place of traditional meals. Related research areas in this discipline include: biotechnology to produce new strains of plants for foods and more efficient manufacture of food components; molecular and structural properties of foods and how they affect the conversion, processing, distribution, storage and acceptance of foods; biosensors to monitor food operations; and development of robot technology in food manufacturing.

As you can see from our discussion above, the study of food science and technology can be quite vast and pervasive. However, the following specific topics may comprise various components of food science and technology courses. The areas covered within each of these components are highlighted herewith.

1. **Food analysis and chemistry**

   Investigation of the basic composition and physical, organic and biochemical properties of food constituents at the molecular level; the changes that food constituents undergo during processing and storage. These areas also involve changes in texture, color, flavor, and determination of the effects of processing on the nutritive value of foods. Techniques used by food analysts for proteins; carbohydrates; lipids, fats and oils; colloids; enzymes; vitamins; emulsifiers; acids; oxidants; antioxidants; pigments and flavors; secondary plant metabolites in food.

2. **Food quality factors and their measurement**

   Appearance; textural, flavour, nutritional, sanitary and keeping factors; quality standards, objective and organoleptic evaluation techniques and programs; consumer acceptance; taste panels; complex changes in the physical and chemical structure of the food as influenced by several intrinsic and extrinsic factors.

3. **Nutritive aspects of food constituents and effect of processing and handling**

   Nutrient stability; effects on nutrients of agricultural practices, handling, processing and storage of raw and processed foods including effects of cultivation, harvest, cleaning, freeze preservation, heat processing, baking, extrusion, moisture removal, fermentation, food additives, ionizing radiation; effects of home preparation and commercial foodservice practices; enrichment and protein complementation of foods; improvement of nutritional quality through plant breeding and role of the government in regulating nutritional value of the food supply.

4. Food microbiology, mycology and toxicology

Use of yeasts, moulds and bacteria in production of foods and food ingredients; microbes in fermentation, processing and preservation; spoilage microorganisms; indicators of food borne pathogens; detection, identification and physiology of microorganisms of importance in foods; microbiological culture; monitoring, testing and sampling methods; the development of methods for prevention of spoilage of processed foods; tools of molecular biology in detection of microbes; psychotrophs, thermophiles and radiation-resistant microorganisms; biology, culture and isolation, and identification of important fungi; quantification of fungal toxins; food toxins and toxicity.

5. Food processing and engineering

Fundamental engineering concepts such as momentum, heat and mass-transport systems; engineering aspects of food processing plant operations and automation; unit operations in food processing, food packaging materials, methods, testing and evaluation; effects on shelf life; economics; process control, optimizing automation; waste management; energy conservation and quality control.

6. Food product development

Food product development is often commodity related. This type of research needs to be carried out in the pilot plants with the equipment that is usually smaller in scale than commercial equipment. Development of newer food products with the application of the knowledge of food science and technology and the evaluation of their quality (sensory and nutritional) and marketability.

7. Commodity topics

All aspects of food science and technology of specific commodity groups, including milk and milk products (fluid milk and derivatives, ice cream and related products, cheeses); meat, poultry and eggs; seafoods; fats, oils and related products; cereal grains; legumes; oilseeds; vegetables and fruits; beverages; confectionary and chocolate products.

8. Food safety and regulation

Food sanitation as related to public health and food plant processing; FDA and USDA rules and regulations; food ingredient labelling; nutrition labelling; food law; food additives; food borne diseases; detection; identification; governmental and nongovernmental agencies concerned with food safety; current issues, such as *salmonella* in eggs.

9. The food industry

Publications of major trade associations; industry standards; structure of the food industry; international food corporations; information on allied industries e.g. packaging (steel, aluminium, glass, paper, plastic); chemical manufactures (acidulants, preservatives, enzymes, etc.); and food machinery and equipment manufactures. Popular or consumer works on home processing or food safety and marketing of food products and food prices.

10. Food processing unit operations

Food processing unit operations are involved in the engineering aspects of food processing, packaging and storage. Heating, cooling, drying, concentrating, textural measurement and separation are all processes that are often used during the processing of food products and can be related to engineering principles.

In addition to the areas discussed above, few emerging trends and developments specific to this subject area are highlighted next.

Emerging trends in the subject area

Increased concern about the nutritional content of technologically derived, refined foods is expressed by both consumers and nutritionists. Dietary guidelines and nutrition education, focus on partially replacing refined foods with whole grains, legumes and other foods, which retain their biochemical integrity. Concern about food safety issues is very strong. Food scientists are responding to these nutritional and safety concerns in a variety of ways, including increased attention to food interactions and bioavailability of nutrients, improved analytical and detection methods, and research and education in food safety. New product development, particularly in the area of reduced-fat and reduced-calorie products is predicted. New processing technologies such as high energy electric pulse processing, freeze concentration and hydrostatic pressure processing show promise. Also, food biotechnology is a growing area i.e. genetically modified food (GM food).

So, now you can understand and appreciate what the study of food science and technology entails. Here, in this course entitled Principles of Food Science, you will find a comprehensive coverage of the various components highlighted above. Some of the components have been included in the Food Safety and Food Microbiology course. Therefore, we recommend that you plan your study in such a manner that both the courses are read side by side. This will help you get a comprehensive understanding on various components of this discipline.

Check your progress Exercise 1

1. The two major underlying principles of consumer satisfaction are,

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2. Mention any two important emerging areas in Food Science and Technology?

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1.3 CARBOHYDRATES IN THE DIET -CLASSIFICATION

There is more carbohydrate (CHO) material than all other organic material in nature. This is due to the fact that carbohydrates make up most of the organic structure of all plants, as well as being present to some extent in all animals. In biological systems, they perform a variety of functions, about which you may have already learnt in the Advance Nutrition Course, Block 1, Unit 3, including their role as structural constituents.

Carbohydrates, are made up of carbon, hydrogen and oxygen, however, other elements like nitrogen, sulphur and sometimes even phosphorus may also be present in carbohydrates. Commonly, but not always, the hydrogen and oxygen in the carbohydrates are present in 2:1 ratio as in water, from which the name carbohydrate (Carbon Hydrate) was derived.

Carbohydrates are sometimes referred as “Saccharides”, which has its origin from the Greek word Sakchron meaning sugar. The simplest carbohydrates are called sugars (or monosaccharides) and these may link together to form more complex carbohydrates (oligo- or poly-saccharides). You may have studied about the classification of carbohydrates in the Nutritional Biochemistry and Advance Nutrition Courses. A simple classification of carbohydrates is presented here as well in Box 1 for your knowledge.

Box 1

Class (Degree of Polymerization)	Sub-Group	Components
Sugars (1-2)	Monosaccharides Disaccharides	Glucose, galactose, fructose Sucrose, lactose, maltose
Oligosaccharides (3-9)	Malto-oligosaccharides Other oligosaccharides	Maltodextrins Raffinose, stachyose, fructo-oligosaccharides
Polysaccharides (>9)	Starch Non-starch polysaccharides	Amylose, amylopectin , modified starches Cellulose, hemicelluloses, pectins, hydrocolloids

Monosaccharides, are the simplest carbohydrate molecules. The most commonly occurring monosaccharides in food are *glucose, fructose* and *galactose*. The formula for glucose is $C_6H_{12}0_6$. It can be represented as shown in the figure 1.1a:

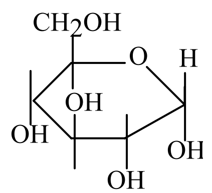

Figure 1.1(a): α-D Glucopyranose

Disaccharides are formed when two monosaccharide molecules join together with the elimination of one molecule of water. They have the general formula $C_{12}H_{22}0_{11}$. Examples of disaccharides are *sucrose* (glucose and fructose), *lactose* (glucose and galactose) and *maltose* (2 molecules of glucose). Have a look at the figures 1.1b and 1.1c for their structures.

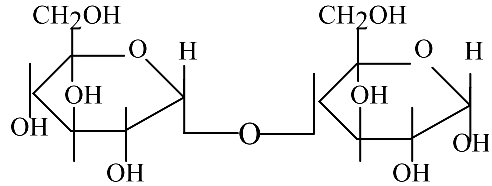

Figure1.1 (b): Maltose

(α-D Glucopyranosyl (1-4) α-D Glucopyranose)

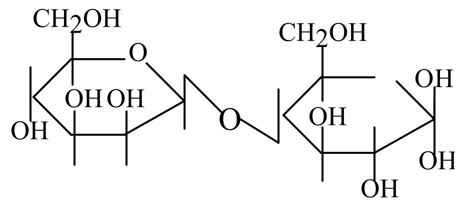

Figure1.1 (c): Lactose

(β-D Galactopyranosyl (1-4) α-D Glucopyranose)

Polysaccharides, on the other hand, are made up of many monosaccharide molecules (usually glucose), joined together. They have the general formula $(C_6H_{10}0_5)_n$ where 'n' is a large number. Examples of polysaccharides are *starch, glycogen, cellulose, beta glucan* and *pectin.*

With a basic understanding of the classification of CHO, next we shall recall the sources of carbohydrates in our diet. Basically, there are two main groups of carbohydrates - starch and sugars - as you may already know. The main sources of carbohydrates in our diet include starchy foods, such as cereals; pulses and potatoes and foods and drinks containing sugars such as milk, fruits and vegetables, jam, confectionery, table sugar and some soft drinks. At an average, starches account for almost 60% of the total carbohydrate intake in the average diet and sugars form around 40%. In addition to starches and sugars, you may have studied about fibre in the context of carbohydrates. Well, ***fibre*** is the term given to a mixture of substances, mainly complex carbohydrates, which cannot be digested in the small intestine in humans, but pass into the large bowel where they are fermented by bacteria. Examples include *cellulose, pectin, guar gum* and *beta glucan.* Fibre is defined as *non starch polysaccharide* (NSP). The substances that make up fibre may have different actions in the body. A small amount of starch is not digested, but passes into the large intestine where it may be fermented by bacteria. This is known as *'resistant starch'* and may have properties similar to NSP.

Please note, in this unit we shall not go into the details of the structure and formula of each of these categories of the carbohydrates. We have already covered this aspect in the Nutritional Biochemistry Course. You may recall reading about the structure and properties of each of these carbohydrates in Block 1, Unit 1 of the Nutritional Biochemistry course. If you have not gone through the Nutrition Biochemistry course, we suggest you take a break here and get your blocks/units related to Carbohydrates. Read and understand these structures and their properties carefully. An understanding of these structures/properties is crucial for your understanding of the functionality of carbohydrates in the diet.

With the basic knowledge about carbohydrates, we are now ready to undertake a detail study on each of these groups of CHOs i.e. sugars, starches and non-starch polysaccharides. In this unit we shall however focus on sugars and sweeteners only. Polysaccharides i.e. starches and non–starch polysaccharides are discussed in the next unit.

1.4 SUGARS: CHEMISTRY AND FUNCTIONALITY

In this section we will learn about the simple carbohydrates called sugars. As you may already know, those carbohydrates that cannot be hydrolysed into simpler forms are known as 'Monosaccharides' or simple sugars. Monosaccharides may be made up of 3-8 carbon atoms. Chemically, these are Poly hydroxy aldehydes or ketones. Depending upon the presence of aldehyde or ketone group in the structure, the carbohydrates may be aldoses or ketoses, and depending upon the number of carbon atoms present in the structure, these may be called as pentose (5 carbon monosaccharide) or a ketohexose (6 carbon monosaccharide) and depending upon the presence of aldehyde or a keto group, it may be called a aldohexose or ketohexose. A list of commonly occurring aldoses and ketoses is given below:

Box 2

	Aldoses	Ketoses
Trioses $C_3H_6O_3$	Glycerose or glycerladehyde	Dihydroxyacetone
Tetroses $C_4H_8O_4$	Erythrose Threose	Erythrulose
Pentoses $C_5H_{10}O_5$	Ribose Arabinose Xylose	Xyloketose
Hexose $C_6H_{12}O_6$	Glucose Mannose Galactose	Fructose
Heptoses $C_7H_{14}O_7$	Glucoheptose Galactoheptose Mannoheptose	

We will not dwell on the structure and properties of simple sugars here. Our focus in this course is to understand the functional role of these molecules in our diet. Do look up the structure and properties of CHO in the Nutritional Biochemistry block 1, unit 1. This information, we repeat, is crucial for your understanding of the functions of sugars. But, first let us look at the common sources of sugars.

The following Table depicts various sugars and their common sources:

Table 1.1 Classification of Sugars, Sources and Characteristics

Classification	End Products on Hydrolysis	Source, Function or Characteristics
Monosachharides		
Pentoses		
Ribose	Ribose	Derived from pentoses of fruits and nucleic acids of meat products & seafood, does not occur in free forms in foods, is an aldose
Xylose	Xylose	Is an aldose
Arabinose	Arabinose	Is an aldose
Hexoses		
Glucose	Glucose	Fruits, Honey, Corn Syrup
Fructose	Fructose	Fruits, Honey, Corn Syrup
Galactose	Galactose	Does not occur in free form in foods
Mannose	Mannose	Does not occur in free form in foods
Disaccharides		
Sucrose	Glucose	Is an aldose
	Fructose	Beet and cane sugars, molasses, maple syrup, comes in many crystal sizes and grades
Lactose	Glucose	
	Galactose	Milk and milk products
Maltose	Glucose	Malt products, low concentrations in plants and processed foods

Now, let us study about the functional role of sugars in food.

1.4.1 The Functional Role of Sugars in Food

From the consumer's point of view, sugars are primarily associated with sweetness. Sweetness is essentially a physiological sensation. Thus it has to be tested by human testers; the sweetness of solutions of different concentrations is compared to that of standard sugar solutions until they appear the same. The ratio of concentrations then gives the sweetness ratio.

The most obvious role of sugar in foods is to impart sweetness, however, there are a number of other roles these play in food systems. For example, in candy making, the structural role of crystallization is usually critical. In baked products, sugar not only contributes to the browning of the product, but it may serve to tenderize the product through its action on both the gelatinization of starch and denaturation of protein. Sugars have numerous other functions as well, which make them important ingredients in many foods. They add flavor and functionality that enhances cooking, also contribute to a safe and varied food supply. Replacement of many of the functions of sugars in foods cannot be readily achieved by other ingredients. Let us get to know a little more about these functions. We start with the basic function sweetness.

1. Sweetness

Sweetness is the most recognized functional property of sweeteners. Our preference for sweetness, regarded as innate, is apparent soon after birth and prior to postnatal learning, and decreases with older age. Sweetness is also associated with feelings of pleasure and appreciation or reward, which contribute to the appeal of sweet foods. The combination of sugars and fats in confections provide a sweet taste and texture that compliment each other. In beverages, sucrose provides sweetness without altering the subtle flavours of the beverage.

The Table below shows sweetness of several common sugars relative to sucrose:

Table 1.2 Sweetness of Sugars

Name	Sweetness
Fructose	1.73
Invert sugar	1.30
Sucrose	1
Glucose	0.74
Maltose	0.32
Lactose	0.16

Look at Table 1.3. It shows solubility of some of the common sugars in water:

Table 1.3 Solubility of Sugars in Water

Name	Solubility in grams/100 ml water
D-Fructose	Highly soluble
D-Galactose	10.3
D-Glucose anhydrous	83
Lactose	8
Lyxose	Highly soluble
Maltose	108
D-Mannose	248
Raffinose	14
Sucrose	179
D-xylose	117

2. Texture

Sugars make an important contribution to the texture of foods, commonly referred to as 'mouthfeel'. For example, glucose syrups in ice-cream provide body and texture, perceived as smoothness. Adding sugar syrup helps to prevent lactose crystallization, which would cause a sandy or grainy texture associated with frozen dairy products. In candy making, controlling the rate and extent of sugar crystallization provides a vast array of different textures. These range from the soft textures of fondants and fudges, where crystallization is minimized, to hard candies where crystallization results in a desired grainy or crystalline structure. Honey has a non-crystallization property, and can therefore be used in confectioneries to maintain a soft and smooth consistency.

In bakery applications, sugars are used to impart flavor, aroma and color. During the mixing process, excess gluten development can make doughs and batters rigid and tough. Addition of sugar will ensure that gluten maintains an optimal elasticity, allowing the dough to expand and rise properly. During mixing, flour protein is surrounded with water, forming gluten strands. The strands have thousands of balloon-like pockets that trap gases produced during leavening. These gluten strands are highly elastic, and allow the batter to stretch as the gases expand. Sugars compete for water with gluten proteins, inhibiting their development and allowing proper volume and tender texture.

Sugars allow the dough to rise at an optimal rate during leavening. The naturally occurring irregular surface texture of the sugar crystals encourages yeast growth and effectiveness by providing an immediate and easily accessible source of nourishment. Under appropriate conditions, the yeast cells break down the sugar crystals, releasing carbon dioxide that causes the dough to rise. Addition of shorteners to the dough allows the air to get trapped in the naturally irregular sugar crystals. As the shortening and sugar are creamed together, the trapped air cells get interspersed in the mixture. During baking, these air cells expand with carbon dioxide and other gases from the leavening agents to ensure just the right volume. The sugars naturally interact with proteins from the beaten eggs to stabilize the foam structure. This makes the egg foam more elastic, allowing it to expand as it takes up gases from the leavening process.

In bakery products, sugar is recrystallized as water is removed during baking, resulting in a crisp texture. This crispness is increased by the effects of browning (Maillard reaction), which takes place when reducing sugars and nitrogen-containing ingredients (e.g. protein) are heated together. You will read about browning later in this section under the appearance function.

Sugars also act to tenderize bakery products by slowing the rate at which starch molecules become interlinked and proteins break down. Glucose, fructose, sucrose and maltose are used in bread making to increase dough yield and prevent excessive stickiness.

While baking unshortened cakes along with sugars help ensure the cakes "set" correctly. As the temperature rises, egg proteins coagulate, or form bonds among each other. Once egg proteins coagulate, the cake "sets," forming its solid, mesh-like structure. Sugars disperse among the egg proteins and naturally interfere with the bond formations, raising the temperature at which they form.

The heat of baking causes the starch in flour to swell from moisture absorption and set in gelatinization. To create a fine, uniformly-grained cake with a soft, smooth crumb texture, the "setting" must be delayed until the optimal amounts of gases are produced by the leavening agents. Sugars are hygroscopic and act to slow the gelatinization process by competing with starch for moisture. This maintains the viscosity of the batter until the optimal amount of gases are produced by the leavening agents, ensuring good texture and volume.

Surface cracking is desirable in most cookies. As sugars re-crystallize, it gives off heat that evaporates the water absorbed during mixing. This combines with leavening gases to expand and cause surface cracking of the dry surface.

We have just learnt about the textural contribution of sugars in our foods. Next, we shall focus on the preservative functions of sugars. But, first we shall take a break and attempt the exercises given under Check Your Progress in exercise 2. This will help you to assess your understanding of functionality of sugars learnt so far. Do check your responses with the answers given at the end of the unit.

Check your Progress Exercise 2

1. Fill in the Blanks:

a) Carbohydrates are classified into ……....…………..……………………………....

b) Two major sources of carbohydrates in our diet are ……………………………….

c) Fibre is the term given to a mixture of substances which ……..…………………………………………………………………………...

d) Resistant starch is………………………………………………………………

e) Honey is better than sugars in confectionery industry because of its ………………………………………………………………………………………

2. Discuss the role of sugars in:

a) Preparation of dough and batters

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b) Formation of egg foam

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c) Baking of cakes

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d) Surface cracking in cookies

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3. Preservation

In many products, sugars play an important role in preservation. The addition of monosaccharides, such as glucose or fructose, to jams and jellies inhibits microbial growth and subsequent spoilage. Sugars have a great affinity for water, thus slowing moisture loss in foods, like baked foods and extending the shelf life of these products. Both honey and invert sugar help to retain moisture due to their high fructose content, as do sorbitol (sucrose alcohol) and corn syrup.

Sugars are added to canned vegetables both to maintain firmness and minimize oxidation when the can is opened. Inhibiting oxidation reactions not only protects against deterioration of texture and flavour, but also the loss of colour resulting from the breakdown of pigments. The interaction between sugars and water controls the moisture in products like cakes and biscuits, to prevent drying out and staleness.

The technique of superior osmotic dehydration which is likely to provide better tasting, more nutritious, environmentally-friendly dried foods for consumers, relies on the principle of osmosis (movement of water and dissolved substances through the membrane to equalize this concentration difference). The principle of osmosis has been used for some time in the food industry. Food material of plant or animal origin is immersed in concentrated solutions of water, containing solutes such as sugar or salt. There is a transfer of water out of the food (dehydration) and a simultaneous transfer of solute into the food (impregnation). By controlling the extent of dehydration and impregnation, it is possible to modify the functional properties of foods. There is a growing interest by the food industry in the process of osmotic dehydration, with the goal of extending the shelf life while enhancing the overall quality of the final products.

4. Fermentation

The production of chemicals by fermenting various sugars is a well-accepted science. Its use ranges from producing beverage alcohol and fuel-ethanol to making citric acid and xanthan gum for food uses. However, the high price of sugar and the relatively low cost of competing petroleum-based fuel has kept the production of chemicals mainly confined to producing ethanol from corn sugar - until now.

Ethanol has been made since ancient times by the fermentation of sugars. All beverage ethanol and more than half of industrial ethanol is still made by this process. Simple sugars are the raw material. Zymase, an enzyme from yeast, changes the simple sugars into ethanol and carbon dioxide. The decomposition of sugar during fermentation is identical with the reactions by which sugar begins to burn during respiration.

The fermentation reaction, represented by the simple equation,

$$C_6H_{12}O_6 \longrightarrow 2\ CH_3CH_2OH + 2\ CO_2$$

is actually very complex, and impure cultures of yeast produce varying amounts of other substances, including glycerin and various organic acids. We can split sucrose into glucose and fructose either by means of a strong acid, such as sulphuric acid, or by an enzyme obtained from yeast, namely saccharase or invertase. In the production of beverages, such as whiskey and brandy, the impurities offer the flavor. Starches from potatoes, corn, wheat, and other plants can also be used in the production of ethanol by fermentation. However, starches must first be broken down into simple sugars. An enzyme released by germinating barley, diastase, converts starches into sugars. Thus, the germination of barley, called malting, is the first step in brewing beer from starchy plants, such as corn and wheat.

Sugars, which are used to activate yeast for fermentation, are important in the brewing and baking industries. The type and the amount of sugar added to the dough in baked products can increase dough yield by influencing the rate of fermentation. Sugars, such as sucrose, glucose and fermentable corn syrups, significantly contribute to sweetness and softness in white breads. In contrast, sugars are either omitted or used in much lower amounts for hard crust breads. In these breads, yeast is activated by sugars that are formed when enzymes present in the flour act on starch.

Sugars that remain after fermentation affect flavour, contribute to the colour and texture of crusts (through non-enzymatic browning and caramelization reactions) and influence overall texture of the product.

5. Appearance

The Browning Reactions are complex reactions which occur when foods are processed. In some the brown flavour is highly desirable and is intimately associated in our mind with the delicacy of the product. In coffee, maple syrup, the brown crust of bread and all baked goods, potato chips, roasted nuts and many other processed foods controlled browning is necessary. Yet in other foods, browning during processing is undesirable and forms off flavour and dull appearance or even objectionable colors. In drying of fruits or vegetables and in canning or concentrating orange juice, it is highly desirable to avoid browning. The presence of carbohydrates in foods is intimately connected with the browning, which occurs. Other compounds are sometimes important but they are the ones which have some of the reactive groups of the reducing sugars and are similar to them in properties. The pigments, which are formed, are high molecular weight polymers whose constitution is difficult to determine. The browning reactions appear to be complicated not only as to the final product but also as to the course of numerous reactions. It has been exceedingly difficult to assess the chemistry of this change in the complex mixtures, which is encountered in almost every food.

Two major types of non enzymatic browning reaction have been recognized to occur in foods during processing.

1. Maillard Reaction: Reaction of aldehyde and ketone groups of sugars with amino compounds (mostly amino acids, peptides, proteins), independent of the presence of oxygen.
2. Caramelization: the change which occurs in polyhydroxycarbonyl compounds (sugars and sugar acids) when they are heated to high temperature independent of the presence of oxygen.

Let us learn about these reactions/changes:

a. Maillard Reaction: The Maillard reaction sometimes called nonenzymatic, nonoxidative browning is simply the reaction between the amino group of a protein or peptide or amino acid and the reducing group of a reducing sugar at high temperature. An amino group from a protein combines with an aldehyde or ketone group of a reducing sugar to produce brown colour and aroma in a variety of foods, including fried foods and baked goods such as breads. It is interesting that the type of sugar and the type of amino acids will impart the "brown" color thus obtained. The color may range from a yellow to red. The key here is the reducing sugar. Those that are effective reducing sugars are fructose, glucose, maltose, galactose and lactose. Surprisingly, table sugar, or sucrose, is not a reducing sugar. The reactivity of glucose on heating contributes to the subtle orange red colour in bread crust that is a result of browning (Maillard reaction). Caramelization of fructose produces a dark brown crust. Breads that contain sucrose often yield a darker, rich-coloured crust than breads prepared with glucose.

b. Caramelization: Caramelization results from the action of heat on sugars at about 175º C. At high temperatures, sugars dehydrate, break down and polymerize into viscous caramels, the chemical changes associated with melting sugars result in a deep brown amber colour and new flavours. Examples are the browning of bread when toasted in which, caramelization takes place under the oven heat, and the sugar adds a golden-brown, flavourful and slightly crisp surface that tastes great and helps retain moisture in the product or the darkening of maple sap when heated to make maple syrup. The carmelization reaction is attributed to a range of browning reactions and flavor developments. Once the melting point has been obtained, sugars will caramelize. Each sugar has its own carmelization temperature. Galactose, sucrose and glucose all carmelizes, around 160°C, but fructose caramelizes at 110°C and maltose caramelizes at about 180°C. Caramel has a pungent taste, is often bitter, is much less sweet than the original sugar from which it is produced, is noncrystalline, and is soluble in water. Both extent and rate of the caramelization reaction are influenced by the type of sugar being heated.

The brown pigments formed are called as 'melanins' or 'melanoids' which are unsaturated polymers. In both cases a carbonyl or polycarbonyl compound is required. When a food is extracted to remove the carbonyl compounds, browning is retarded or eliminated. The plan showing the various steps of non-enzymatic browning is presented in figure 1.2.

Figure 1.2: Plan showing various steps of non-enzymatic browning

It is obvious from figure 1.2, that browning may occur by compounds entering at any point. In the first reaction, aldoses and ketose react with amines and the reaction is known as *Amadori reaction*.

The product of the reaction can undergo number of fates depending upon the conditions of the reactions as can be seen in figure 1.2. It can, in neutral or acidic media, lose water and form a ring compound of the Schiff's base of hydroxymethyl furfural, or furfural and then eliminate the amine to form the free hydroxy methyl furfural or furfural. In the dry state, it can form reductones which have high reduction potential. Or, finally, the product can undergo fission to form small molecules such as acetol (CH_3 $COCH_2OH$), pyruvaldehyde (CH_3COCHO), diacetyl ($CH_3COCOCH_3$) and others. In the diagram shown, it is obvious that all of those compounds react with amines to form aldimines or ketimines or polymerize to aldols and similar large molecules, which subsequently react with amines. The final brown pigments are produced that contain nitrogen.

The second browning reaction is *caramelization*. Sugars will show caramelization when heated at relatively high temperatures. This type of reaction is markedly affected by high pH. While the browning of these carbohydrates is not as rapid as in the presence of amino compounds, it is accelerated in the presence of carboxylic acid, salts of these acids, phosphates and metal ions. These accelerators are commonly present in foods. The nitrogen free intermediates formed in carbonyl amino browning reactions are also produced in non amino browning The formation of 1,2 enolization, furfural and hydroxymethyl furfural by dehydration and sugar fission products has been demonstrated in some of the model systems. It has also been shown that these intermediates will form colored polymers in the absence of amino compounds. Thus this fits well in the above Figure after Amadori rearrangement forming different nitrogen free polymers.

6. Freezing Point

Sugars are effective in lowering the freezing point of a solution, which is important in manufacturing frozen desserts and ice-cream products. Monosaccharides and corn syrups, containing a high proportion of low molecular weight sugars are most effective at lowering the freezing point. This property ensures smaller ice-crystals and greater smoothness of the product. The use of corn syrup sweeteners in sherbets also helps to prevent crystallization of sugars and promotes a smoother product.

7. Antioxidant Activity

Many carbohydrates are excellent scavengers for metal ions. Glucose, fructose and sugar alcohols (sorbitol and mannitol) have the ability to block the reactive sites of ions, such as copper, iron and to a lesser extent, cobalt. This is characteristic of monosaccharides and aids in food preservation by retarding catalytic oxidation reactions. Furthermore, Maillard reaction products are known to have antioxidant properties in food systems. For this reason, some mixtures of Maillard reaction products have been employed in the food industry as food additives for biscuits, cookies and sausages.

8. Miscellaneous Applications

Sugars are used in Custards, puddings, pie fillings and meringues depending on the sugar to perform vital chemical and physical functions.

a. Custards

While flour protein forms the structure of baked goods, custards are composed of egg protein structures. If the egg white solidifies too soon during cooking, the liquid ingredients form droplets in a process known as “Syneresis” or “weeping." Sugars delay the coagulation of egg proteins and break up clumps of protein molecules, so they finely disperse in the liquid mixture and provide a smooth and stable consistency.

b. Puddings, Sauces and Pie Fillings

When dry starch is added directly to a hot liquid, the particles on the outside tend to cook first, lumping the raw starch particles. The lumps are unpalatable and prevent proper thickening. Adding sugars to starches before the hot liquid ensures the starch particles disperse evenly into the mixture.

c. Meringues

Egg whites beaten for a meringue hold air bubbles because the mechanical action of the beaters partially coagulates the egg protein. Sugars make the protein structure more adhesive and increase its ability to hold air bubbles, resulting in a stiffer, higher and more stable form.

d. Icings

Sugars provide sweetness, flavor, bulk and structure to icings and frostings. In addition to sweetness and flavor, icings also function as a barrier to moisture, extending the freshness.

e. Frozen Dessert Applications

Sugars enhance the creamy texture and pleasing taste of frozen desserts such as ice cream, ice milk, frozen custard and sherbet.

Reducing sugars, such as glucose, fructose, maltose and lactose are recommended for ice cream. Somewhat higher proportions are used for lower fat desserts, such as ice milk and sherbet, in order to counterbalance the reduced amount of butter-fat. When cream is replaced with lower fat ingredients, such as milk or fruit puree, additional amounts of sugars are necessary to ensure a smooth, creamy mouthfeel and balanced flavor.

***Flavors and Mouthfeel*:** In frozen desserts, sugars balance flavor and mouthfeel. Since low temperatures tend to numb the taste buds, sugars enhance flavors, thereby eliminating the need for additional flavor ingredients. They also increase viscosity (thickness), imparting a thick and creamy mouthfeel.

Check your Progress-Exercise 3

1. State whether the following statements are true or false.

a) Addition of sugars to jams and jellies slows down the moisture loss, which extends their shelf life.

b) Maillard reaction and caramelization involve the reaction of reducing group of sugar and amine.

c) In Amadori reaction, aldoses and ketoses react with carboxyl group.

d) The presence of an acid does not have an affect on the process of caramelization.

2. Fill in the blanks:

a) Sugars are added to canned vegetables to ………………………………………………………………………………………

b) The principle of osmosis involves ………………………………………………………………………………………

c) Sucrose can be split into its constituents by the action of ……….. …………………… or ……………………………………………………………

d) The dark pigments produced by Maillard Reaction are termed as…………………

e) Sugars are important constituents of frozen desserts as they………………………………………………………………………………….

3. Explain the following in 1-2 lines:

a) Maillard Reaction

………………………………………………………………………………………

………………………………………………………………………………………

b) Caramelization

…………………………………………………………………………………

…………………………………………………………………………………

c) Weeping

…………………………………………………………………………………

…………………………………………………………………………………

d) Amadori Reaction

…………………………………………………………………………………

…………………………………………………………………………………

1.5 SWEETENERS

As a group, artificial sweeteners are classed as "non-nutritive". Thus, they provide sweet sensation to the tastebuds, without raising blood sugar levels or insulin, and are useful for weight-loss because they are calorie- and carbohydrate-free.

Artificial sweeteners, like saccharin, nutrasweet (aspartame) and the cyclamates, provide sugar-like taste and they are far sweeter than the sugars themselves. Small amounts of these synthetic chemicals can replace sugars. Artificial sweeteners provide taste properties for those who wish to reduce calories, or those with illnesses like diabetes whose body cannot tolerate sugars. The artificial sweetener, saccharine, was discovered accidentally in the 19th century. A chemist tasted sweetness on his hands and his observation led to the identification of a particular chemical 500 times sweeter than sugar, which has served as a substitute for sugar for more than 100 years. The chemicals shown in Figure 1.3 are all artificial sweeteners i.e. sugar substitutes.

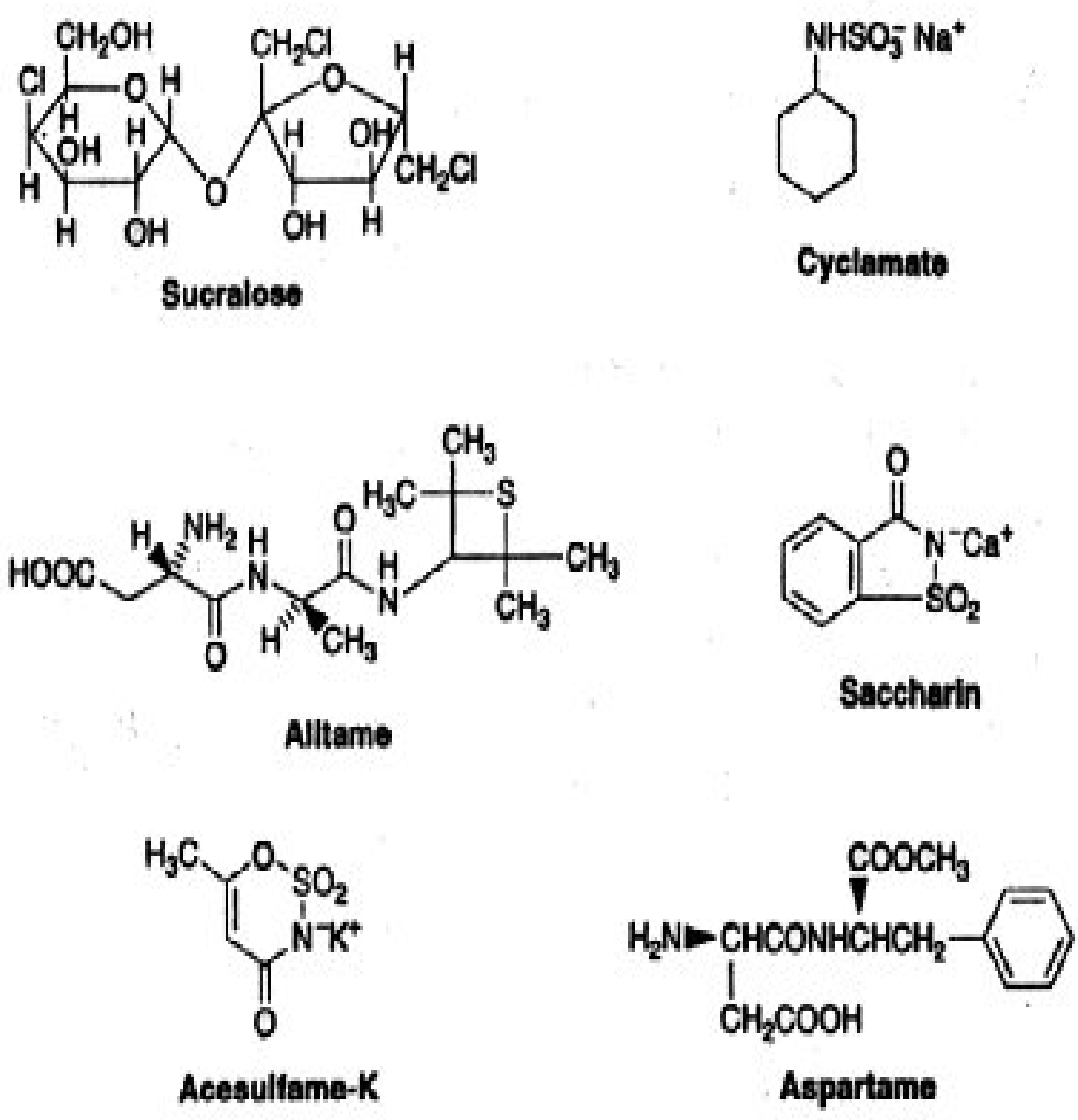


Figure 1.3: Artificial Sweeteners

Some of these are available as tablets, as sugar substitute and others appear as ingredients in many food products, not just in 'diet' foods. Out of the compounds shown, aspartame finds maximum use in the food and other products. The chemical name for aspartame is N-L-*α-**aspart**yl-L-phenyl**a**lanine 1-**m**ethyl **e**ster*, thus the name *aspartame* was extracted. In 1965, James Schlatter, of the G. D. Searle pharmaceutical company, inadvertently *tasted an experimental compound* that he had synthesized in an attempt to discover a better gastric hormone inhibitor, an ulcer drug. This unexpected and fortunate event (for, as we all know, we are instructed to limit exposure to chemicals with unknown properties) led to the development, approval, marketing, and acceptance of the most widely used "artificial" sweetener in the world called ‘aspartame’ more commonly known by its trademark name, *NutraSweet*. However, one of the drawbacks of aspartame is its instability to heat and acid. Some interesting concepts related to aspartame are highlighted in the aspartame concept presented in figure 1.3.

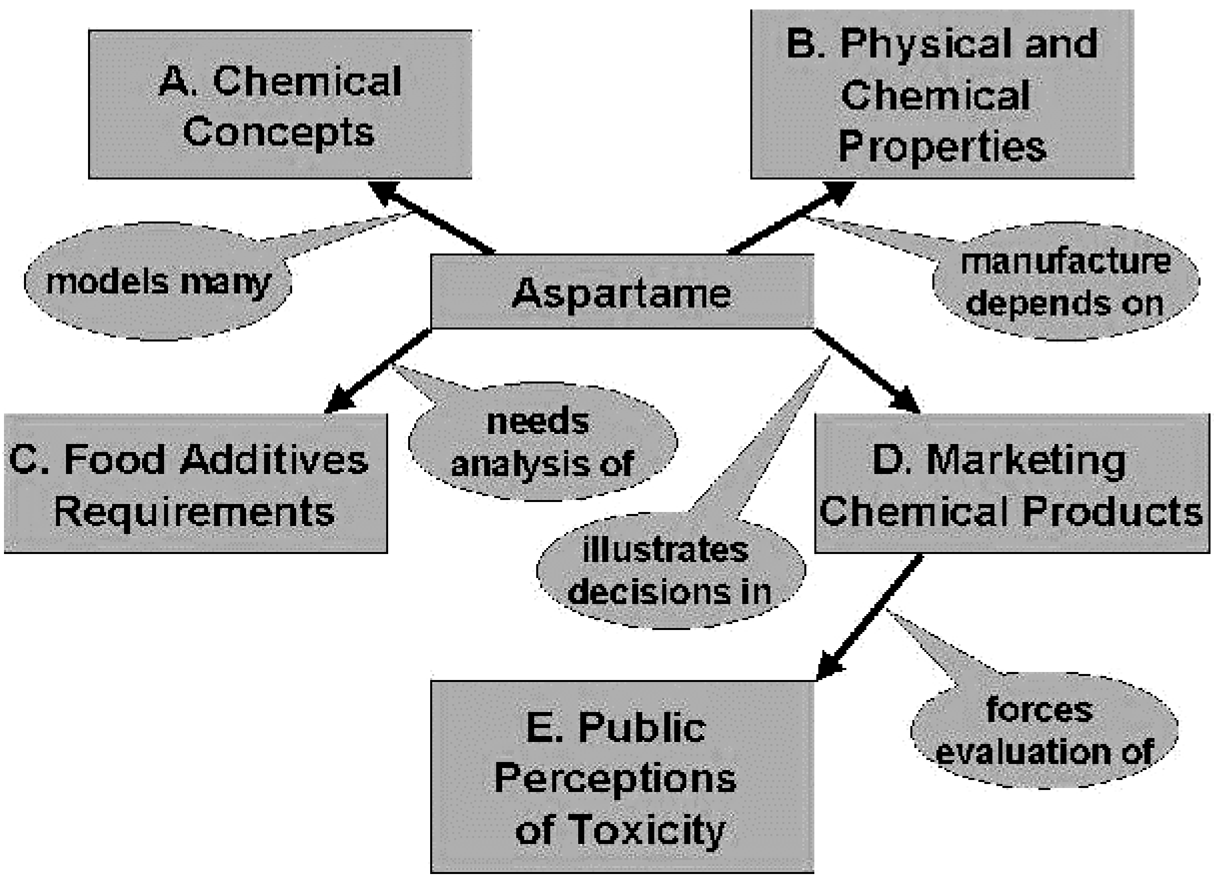


Figure 1.4: Aspartame concept

Acesulfame-K (potassium salt of 6-methyl-1, 2, 3-oxathazin-4(3H)-one 2, 2 dioxide) is a sweetener which is commonly used in dry mixes, table uses and chewing gum. It is 200 times as sweet as sugar and it is not metabolised and is thus non-caloric. Food products often contain a mixture of sweeteners. This is because it has been found that they have a synergistic effect whereby the sweetness of a mixture is greater than that of the individual components. This means that less amount can be used to get the same apparent sweetness.

Sucralose (1,6-dichloro-1,6-dideoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D-galactopyranoside) is the only non-nutritive sweetener based on sucrose. Its structure is shown in the figure 1.3 for your better understanding. It is selectively chlorinated and the glycosidic link between the two rings is resistant to hydrolysis by acid or enzymes thus, it is not metabolised. It is 400-800 times sweeter than sucrose. It is highly soluble in water and is stable to heat.

Alitame (L-α-aspartyl-N-(2,2,4,4-tetramethyl-3-thietanyl)-D-alaninamide), as illustrated in figure 1.3, is a sweetener based on an amino acid, like aspartame. It is 2000 times as sweet as sugar and although it is metabolised, very little is needed and it is noncaloric. (1 g can replace 2 kg of sucrose). Alitame has a 'sweet and clean taste'.

The oldest artificial sweetener is saccharin (the calcium or sodium salt of 1, 2-benzisothiazol-3(2H)-one 1, 1-dioxide) as shown in the figure 1.3, is used for over a century. It is 300 times as sweet as sucrose, but many people don't like its bitter aftertaste. It is also controversial as some animal studies showed that massive doses of saccharin produced cancer. However, it was not banned as the evidence of harm to humans wasn't there and the levels fed to rats were so high for its carcinogenic effect. It is widely used in a variety of products and the health risk, compared to the risk of over-consumption of sucrose, appear to be much lesser.

Another sweetener is cyclamate (sodium cyclohexylsulphamate). Have a look at its structure as shown in the figure 1.3. It is only 30 times as sweet as sucrose, which does not give it a strong competitive advantage.

Several minor sweeteners are under evaluation which were derived from natural sources: For e.g., stevioside from a South American plant; glycyrrhizin from licorice root; thaumatin, a mixture of proteins from a West African fruit.

The most interesting potential sweetener from a chemical point-of-view is left-handed Sucrose. It is also called invert sugar. Let us learn about this natural sweetener.

INVERT SUGAR

Invert sugar is sucrose, which can be hydrolysed to split the disaccharide into its component sugars, fructose and glucose. It is called invert sugar because hydrolysis of sucrose causes the solution to alter the rotation of polarised light, an effect known as the inversion of sucrose. This inversion takes place due to the presence of either enzyme or acid. The fructose and glucose combination is much more soluble than the sucrose crystals and so the consumer perceives syrup that is very sweet.

High Fructose Corn Syrup (HFCS) is manufactured from corn starch. The corn starch is hydrolyzed by acid or enzyme and then the resulting glucose is "inverted" into fructose. The percentage of inversion can be changed by altering the processing conditions. This is another processing method in foods, particularly in the sweetener area.

In food systems, acid and enzymes hydrolyze and invert the sugars into their component monosaccharides. The implications of this are that, any product, which has an acid compound, may bring about the hydrolysis of sucrose into fructose and glucose. This is particularly important, if the product is heated. Fructose and glucose being reducing sugars (whereas sucrose is not), enhance browning. They are more soluble and more hygroscopic than sucrose. Crystallization of sugar can be a problem, in a variety of products. For example, in the candy industry.

Table 1.4 depicts the relative sweetness of the various sweeteners. It is the standard to compare the sweetness of a product to sucrose. Sucrose is 100 and is the standard for comparison.

Sugars and sweetners	**Rating**
Fructose	140
HFCS	120-160
Sucrose	100
Glucose	70-80
70DE corn syrup	70-75
Regular corn syrup	50
Maltose	30-50
Galactose	32
Lactose	20
High conversion corn syrup	65
Regular conversion corn syrup	50
HFCS-90%	120-160
HFCS-55%	>100
HFCS-42%	100
Invert Sugar	50
Sorbitol	50
Xylitol	100
Saccharin	30,000-50,000
Sucrol [Dulcin]	20,000
Honey	97
Molasses	74
Sorghum Syrup	69
Corn Syrup	30
Aspartame	180x
Sucralose	600x
Saccharin	300x

Well then, you have a wide range of sweeteners to choose from. Which sweetener to select? Is aspartame better or saccharine? Very often we are confronted by such issues. The bootom line is look for the following considerations while selecting a sweetener:

- the desired taste profile of the food
- the interaction between sugars and/or sweeteners
- the interaction between sugars and sweeteners and other ingredients
- the cost of sugars/sweeteners

Check Your Progress-Exercise 4

1. Fill in the blanks:

a) Artificial sweetners are classed as 'non-nutritive' because they ………………………………...

b) The chemical name of Aspartame is……………………………………………..

c) An example of invert sugar is……………………………………………………

d) Arrange the following sweetners in increasing order of sweetness.
Glucose, Sucrose, Invert sugar, Fructose, Saccharin, honey, Aspartame
…………………………………………………………………………………

e) A few considerations to be kept in mind while selecting sweetener are …………………………………………………………………………………
…………………………………………………………………………………

f) The most commonly used sweetner is……………………………………………..

g) The comparative sweetness ranking of other sweetners is made by considering the sweetness of sucrose as…………………

1.6 LET US SUM UP

Food Science and Technology are so inextricably linked that usually these are treated as one field of study. While Food Science deals with the study the nature of foods, the causes of their deterioration and the principles underlying food processing, Food Technology is the application of food science to the selection, preservation, processing, packaging, distribution and use of safe, nutritious, and wholesome food. It is the application of the principles and facts of science, engineering, and mathematics to the processing, preservation, storage, and utilization of foods with the final aim of delivery of safe, nutritious and cost effective food to the customer.

The simplest carbohydrates are called sugars (or monosaccharides). In this unit you learnt about the major use of sugars in the food industry that is to provide the sweetness in different products. Apart from that, the sugars have a number of other functions in the food systems. An important function of the sugars is their involvement in the process known as *non-enzymatic browning*, which is desirable in various food products, especially in bakery products, but undesirable in other. However, in the patients, who are not able to metabolise sugars (particularly Diabetics), various sugar replacers, also known as artificial sweeteners, are available (with low to no calorific value), the major player of artificial sweetener is aspartame.

1.7 GLOSSARY

Biosensors	:	A device that uses biological materials to monitor the presence of various chemicals in a substance.
Caramelization	:	Formation of dark colored complexes when sugars are heated at high temperature
Complex Carbohydrates	:	Also known as Polysaccharides. Made up of many monosaccharide units joined together in a linear or branched fashion
Invert sugar	:	Hydrolysed sugar to produce the constituents ie., glucose and fructose
Modified starches	:	Modification of starch structure by physical / chemical means to attain a particular functional property(ies)
Monosaccharides	:	Simplest form of carbohydrates which can not be hydrolysed further into smaller units.
Reducing sugar	:	Sugars with free aldehyde or ketone group, capable of

reducing cupric to cuprous form in alkaline medium

1.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check your Progress-Exercise 1

1 The major underlying principles of consumer satisfaction are: (any two of the following):

- Safety
- Organoleptic properties
- Affordability
- Nutrition

2. The emerging areas in Food Science and Technology are: (any two of the following):

- Food Safety
- High energy electric pulse processing
- Freeze concentration
- Hydrostatic pressure processing

Check Your Progress-Exercise 2

1. a) Monosaccharides, Disaccharides, Polysaccharides

   b) Starches and Sugars

   a) cannot be digested in small intestine

   b) undigested starch which passes into large intestine, where it is fermented by bacteria

   c) non-crystallization property.

2.

a) Addition of sugar ensures that gluten maintains an optimal elasticity allowing the dough to rise and expand properly.

b) Sugars interact with proteins from the beaten eggs to stabilise the foam structure, making it more elastic.

c) In cakes, the egg proteins coagulate to form a mesh-like structures. Sugars disperse among the egg proteins and raise the temperature at which the form. They also slow gelatinization process by competing with starch for moisture, which maintains viscosity of batter and ensures good texture and volume.

d) Re-crystallization of sugars gives off heat that evaporates the water absorbed during mixing. This combines with leavening gases to expand and cause surface cracking of the dry surface of cookies.

Check Your Progress Exercise 3

1.

a) True

b) False

c) True

d) False

2.

a) maintain firmness and minimize oxidation

b) movement of water and dissolved sustances through the membrane

c) H_2SO_4 or Zymare

d) Melanins

e) Balance flavor and mouthfeel.

3.

a) Reaction of aldehyde and ketone compounds with amine groups, mostly amino acids, peptides and proteins at a high temperature is referred to as Maillard reaction. It is also called as non-enzymatic, non oxidative browning.

b) Caramelization is the change which occurs in polyhydroxycarbonyl compounds when heated to high temperatures at about 175^oC.

c) The early solidification of egg-whites resulting in the formation of droplets of the liquid ingredients is referred to as weeping.

d) Amadori reaction is the reaction of aldoses and ketoses with amines.

Check Your Progress-Exercise 4

1.

a) Calorie and carbohydrate-free

b) N-L-X aspartyl-L- phenylalanine 1-methylester

c) Sucrose

d) Invert sugar, honey, Glucose, Sucrose, Frustose, Aspartame, Saccharin

e) taste profile of food, interaction between sugars, sweetners and other ingredients, and cost.

f) Aspartame

g) 100.

UNIT 3 LIPIDS

Structure

3.1 INTRODUCTION

After a detailed study on carbohydrates, we now move on to the next structural component of all living cells, the lipids. Lipids are the major components of adipose tissue and together with the proteins and carbohydrates they constitute the principal structural components of all living cells.

Lipids in food exhibit unique physical and chemical properties. Their composition, crystalline structure, melting properties and the ability to associate with water and other non-lipid molecules are especially important to their functional properties in many foods. We will learn about these properties and the role of lipids in product preparation in this unit. Further, during the processing, storage and handling of foods, lipids undergo complex chemical changes and react with other food constituents, producing numerous compounds, both desirable and deleterious to the food quality. What are these deteriorative changes in food lipids? Are there any means of controlling such changes? These are the other issues highlighted in this unit.

You will realize, that like in previous two units, here too we have not dwelt much on the structural component of lipids. The reason being that the structure, physical/chemical properties have been discussed in the Nutritional biochemistry course. We do not wish to duplicate the effort here and make the content bulky. However, we do advise you to look up the relevant block/unit in the Nutritional Biochemistry course before you start studying this unit. Best approach would be to have those blocks handy so that you can refer to them as and when required.

Objectives

After studying this unit, you will be able to:

- enumerate the important sources of food lipids,
- describe the basic composition of food lipids,
- discuss the role of food lipids in product preparation,
- debate on the importance of functionality of food lipids with reference to food processing and quality of finished products, and
- recognize the deteriorative changes in food lipids and means of controlling such changes.

3.2 LIPIDS – INTRODUCTION AND SOURCES

In its broadest sense, 'lipids' defines substances as oils, fats and waxes which can be only characterized by a large array of properties. They are in general:

- coming from plant and animal origin;
- insoluble or immiscible with water but soluble in organic solvents such as chloroform, ether, benzene, acetone; and
- formed of long-chain hydrocarbon groups (carbon and hydrogen), but may also contain oxygen, phosphorous, nitrogen and sulphur.

Glycerol esters of fatty acids, which make up to 99% of the lipids of plant and animal origin have been traditionally called *fats and oils*. This distinction, based solely on whether the material is solid or liquid at room temperature, is of little practical importance and the two terms are often used interchangeably.

Food lipids are either consumed in the form of *"visible"* fats, which have been separated from the original plant or animal sources, such as vegetable oil and butter, or as constituents of basic foods, such as milk, cheese and meat. This is referred to as *'invisible fat'*. You already know that dietary lipids play an important role in nutrition. They supply calories and essential fatty acids, act as vitamin carriers and increase the palatability of food. The largest supply of vegetable oil comes from the seeds of soy bean, cottonseed, peanut and the oil-bearing trees of palm, coconut and olive.

Oil–bearing fruits, nuts and seeds have been grown and used for food for many centuries. More than 100 varieties of plants are known to have oil–bearing seeds, but only a few have been commercialized. The largest source of vegetable oil at present is the seeds of annual plants such as soybean, cottonseed, peanut, sunflower, safflower, mustard and rapeseed. Many of the oil–bearing seeds are not only a source of oil, but also protein, the protein portion has the most value. A second source of vegetable oils is the oil–bearing fruits and nuts of trees such as coconut, palm, palm kernel and olive. The oil from the palm and olive is extracted from the fruit rather than the seed of the fruit. All the oil–bearing trees require a relatively warm climate, two of which are tropical: coconut and palm.

Oil contents for vegetable oil–bearing materials vary between 18% and 68% of the total weight of the seed, nut, kernel or fruit as indicated in Table 3.1.

Table 3.1: Oil Content of few Vegetable Oil Sources

Oil Bearing Material	Oil Content (%)
Coconut	65 – 68
Cottonseed	18 – 20
Olive	25 – 30
Palm	45 – 50
Palm kernel	45 – 50
Peanut	45 – 50
Safflower	30 – 35
Soybean	18 – 20
Sunflower	35 – 45

Meat fats are derived almost entirely from three kinds of domestic animals: hogs, cattle and sheep. Milk of cow and buffalo is an important source of fat in the form of either butter or ghee. Bulk of the world's milk fat production consists of butterfat from cow's milk, and in India, butter and ghee have a well-established place in the culinary practices.

Fats and oils are a unique class of agricultural products in that a high degree of interchangeability among them is possible for many products and uses. Additional processing and/or blending of one or more source oils may be necessary for a satisfactory substitution. Knowledge of the physical and chemical properties of each individual raw material is necessary to successfully duplicate or improve on the functionality of the original source oil's functionality. To understand this, we need to first look at the composition of lipids. The next section is devoted to the classification and composition of lipids.

3.3 LIPIDS - CLASSIFICATION AND COMPOSITION

The classification and categories of lipids is presented in this section. There may be different ways of classifying lipids. A general classification is presented herewith.

You may recall reading about the classification of lipids in the Advance Nutrition Course.

3.3.1 Classification of lipids

A general classification of lipids based on their structural components is presented in table 3.2. Such a classification, however, is possibly too rigid for a group of compounds as diverse as lipids and should be used only as a guide. The table gives the major, sub-class and description of the various lipids.

Table 3.2: Classification of lipids

Major Class	Subclass	Description
Simple lipids	Acylglycerols	Glycerol + fatty acids
	Waxes	Long–chain alcohol + long-chain fatty acids
Compound lipids	Phosphoacylglycerols (or glycerophospholipids)	Glycerol + fatty acids + phosphate + another group usually containing nitrogen
	Sphingomyelins	Sphingosine + fatty acid + phosphate + choline
	Cerebrosides	Sphingosine + fatty acid + simple sugar
	Gangliosides	Sphingosine + fatty acid + Complex carbohydrate moiety that includes sialic acid
Derived lipids	Materials that meet the definition of a lipid but are not simple or compound lipids	Examples: fatty acids, carotenoids, steroids, fat-soluble vitamins

It should also be recognized that other classifications may sometimes be more useful. For example, the sphingomyelins can be classed as phospholipids because of the presence of phosphate. The cerebrosides and the gangliosides can also be classified as glycolipids because of the presence of carbohydrate and the sphingomyelins. The glycolipids can be classed as sphingolipids because of the presence of sphingosine.

The most abundant class of food lipids is the acylglycerols, also known as *glycerol esters of fatty acids*, which dominate the composition of depot fats in animals and plants. The polar lipids are found almost entirely in cellular membranes (phospholipids being the main component of the bilayer), with only very small amounts in depot fats. In some plants, glycolipids constitute the major polar lipids in cell membranes. Waxes are found as protective coatings on skin, leaves and fruits. Major components of lipids are the acylglycerols. They are the esters of glycerol and fatty acids, having a varying chain length. Fatty acids are aliphatic monocarboxylic acids that can be liberated by hydrolysis from naturally-occurring fats. For example, oleic acid, which is a common fatty acid found in acylglycerols, has 18 carbon atoms in its chain. The carboxyl (COOH) group of the acids forms the ester by combining with the hydroxyl (OH) group of glycerol. There are 3 hydroxyl groups in a glycerol molecule. If all the three groups are forming ester linkage with fatty acids, the resulting compound is called a triacylglycerol or a *triglyceride*. Structure of a triacylglycerol is shown:

$$CH_2OOC\,(CH_2)_{16}CH_3$$

$$|$$

$$CH_3\,(CH_2)_{16}COOHCH$$

$$|$$

$$CH_2OOC\,(CH_2)_{16}\,CH_3$$

The compound shown here is tristearoylglycerol, also known as glycerol tristearate. This is a triester of glycerol with stearic acid. Many other fatty acids either saturated or unsaturated and having varying chain length are present in triacylglycerols.

Common fatty acids present in acylglycerols are stearic acid (C-18, saturated), oleic acid (C-18, monounsaturated), linoleic acid (C-18, diunsaturated) and palmitic acid (C-16, saturated).

You came across the terms saturated and unsaturated in the above section. Let's understand these terms better.

3.3.2 Categories of Fats and Oils

As a student of nutrition, you already know that fatty acids are the lipid-building blocks. It is customary to divide the fatty acids into different groups, e.g., saturated and unsaturated ones. *Saturated* meaning they have as many hydrogens bonded to their carbons as possible and *unsaturated* meaning with one or more double bonds connecting their carbons, hence, fewer hydrogens. This particular division is useful in food technology because saturated fatty acids have a much higher melting point than the unsaturated ones, and the ratio of these fatty acids is of major importance for the physical properties of a fat or oil.

Table 3.3a. Saturated fatty acids

Systematic Name	Common Name	Formula	Short-hand Description
n-Butanioc	Butyric	$CH_3\ (CH_2)_2\ COOH$	4:0
n-Hexanoic	Caproic	$CH_3\ (CH_2)_4\ COOH$	6:0
n-Octanoic	Caprylic	$CH_3\ (CH_2)_6\ COOH$	8:0
n-Decanoic	Capric	$CH_3\ (CH_2)_8\ COOH$	10:0
n-Dodecanoic	Lauric	$CH_3\ (CH_2)_{10}\ COOH$	12:0
n-Tetradecanoic	Myristic	$CH_3\ (CH_2)_{12}\ COOH$	14:0
n-Hexadecanoic	Palmitic	$CH_3\ (CH_2)_{14}\ COOH$	16:0
n-Octadecanoic	Stearic	$CH_3\ (CH_2)_{16}\ COOH$	18:0

n-Eicosanoic	Arachidic	$CH_3 (CH_2)_{18} COOH$	20:0
n-Docosanoic	Behenic	$CH_3 (CH_2)_{20} COOH$	22:0

Some of the more important saturated fatty acids with their systematic and common names are listed in table 3.3a, and some of the unsaturated fatty acids in table 3.3b. The naturally occurring unsaturated fatty acids in fats are almost exclusively in the *cis* – form, although *trans* – acids are abundant in ruminant milk fats and in catalytically hydrogenated fats. What are cis and trans-acids? You may have learnt about this concept in the Nutritional Biochemistry Course. We suggest you look up Block 1, Unit 2 of the Nutritional Biochemistry course for understanding this concept.

Table 3.3 b. Unsaturated Fatty Acids

Systematic Name	Common Name	Formula	Short-hand Description
Hexadec-9-enoic	Palmitoleic	$CH_3 (CH_2)_5 CH=CH (CH_2)_7 COOH$	16:1
Octadec-9-enoic	Oleic	$CH_3 (CH_2)_7 CH=CH (CH_2)_7 COOH$	18:1
Octadeca-9:12-dienoic	Linoleic	$CH_3 (CH_2)_4 (CH=CH.CH_2)_2 (CH_2)_6 COOH$	18:2
Octadeca-9:12:15-trienoic	Linolenic	$CH_3 (CH_2)_3 (CH=CH.CH_2)_3 (CH_2)_6 COOH$	18:3
Eicosa-5:8:11:14-tetraenoic	Arachidonic	$CH_3 (CH_2)_4 (CH=CH.CH_2)_4 (CH_2)_2 COOH$	20:4
Docos-13-enoic	Erucic	$CH_3 (CH_2)_7 CH=CH (CH_2)_{11} COOH$	22:1

Table 3.4 gives the composition of common vegetable oils.

Table 3.4: Component Fatty acids of some vegetable oils (Wt %)

	Fatty Acids								
Oil	**16:0**	**18:0**	**20:0**	**22:0**	**24:0**	**16:1**	**18:1**	**18:2**	**18:3**
Cottonseed	22	3	Tr	---	---	1	19	54	1
Peanut	11	2	2	3	1	Tr	48	32	---
Sunflower	7	5	---	---	---	---	19	68	---
Corn	11	2	Tr	Tr	---	---	28	58	---

Sesame	9	4	---	---	---	---	41	45	---
Olive	13	3	Tr	---	---	2	71	10	1
Palm	45	4	---	---	---	---	40	10	---
Soybean	11	4	Tr	Tr	---	---	24	54	7
Safflower	7	2	Tr	---	---	---	13	78	---
*Mustard	3.5	---	---	---	---	---	22.4	24.4	13.7

* also contains around 40% Erucic acid (22:1)

Tr- Traces

In continuation of our classification of lipids, it is important to realize that edible fats are traditionally classified into the following subgroups:

Milk Fats

Fats of this group are derived from the milk of ruminants, particularly cows and buffaloes. Although the major fatty acids of milk fat are palmitic, oleic and stearic, this fat is unique among animal fats in that it contains appreciable amounts of the shorter chain fatty acids (C4 to C12), small amounts of branched and odd numbered acids and fatty acids with trans-double bonds.

Lauric Fats

Fats of this group are derived from certain species of palm, such as coconut. The fats are characterized by their high content of lauric acid (40 – 50%), moderate amounts of C6, C8 and C10 fatty acids, low content of unsaturated acids and low melting points.

Vegetable Butters

Fats of this group are derived from the seeds of various tropical trees and are distinguished by their narrow melting range, which is due mainly to the arrangement of fatty acids in the triacylglycerol molecules. In spite of their large ratio of saturated to unsaturated fatty acids, trisaturated acylglycerol are not present. The vegetable butters are extensively used in the manufacture of confections, with cocoa butter being the most important member of the group.

Oleic – Linoleic Fats

Fats in this group are the most abundant. The oils are all of vegetable origin and contain large amounts of oleic and linoleic acids, and less than 20% saturated fatty acids. The most important members of this group are cottonseed, corn, peanut, sunflower, safflower, olive, palm and sesame oils.

Linolenic Acids

Fats in this group contain substantial amounts of linolenic acid (C_{18} triunsaturated). Examples are soybean, mustard, rapeseed, flaxseed and wheat germ hempseed and perilla oils, with soybean being the most important. The abundance of linolenic acid in soybean oil is responsible for the development of an off-flavour problem known as 'flavour reversion'.

Animal Fats

This group consists of depot fats from domestic land animals (e.g., lard and tallow), all containing large amounts of C16 and C18 fatty acids, medium amounts of unsaturated acids, mostly oleic and linoleic and small amounts of odd numbered acids. These fats also contain appreciable amounts of fully saturated triacylglycerols and exhibit relatively high meting points. Egg lipids are of particular importance because of their emulsifying properties and their high content of cholesterol.

The lipid content of whole eggs is approximately 12%, almost exclusively present in the yolk, which contains 32 – 36% lipid. The major fatty acids in egg yolks are 18: 1 (38%), 16: 0 (23%), and 18: 2 (16%). Yolk lipids consist of about 66% triacylglycerols, 28% phospholipids and 5% cholesterol. The major phospholipids of egg yolk are phosphatidylcholine (73%) and phosphatidylethanolamine (15%).

Marine oils

These oils typically contain large amounts of long – chain omega-3-polyunsaturated fatty acids, with up to six double bonds and they are usually rich in vitamins A and D. Because of their high degree of unsaturation, they are less resistant to oxidation than other animal or vegetable oils.

With this, we come to the end of first part of this unit i.e., the introduction, classification and composition of lipids. Look up the points to remember given herewith. They are the useful hints/tips for remembering the concept on your finger tips. Read them carefully.

Points to Remember

1. Lipids consist of group of compounds that are generally soluble in organic solvents but only sparingly soluble in water.
2. Glycerol esters of fatty acids (Acylglycerols) which make up to 99% of the lipids of plant and animal origin have been traditionally called fats and oils.
3. Common fatty acid present in acyl glycerols are stearic acid (C-18, saturated), oleic acid (C-18, monounsaturated), linoleic (C-18, di unsaturated) and palmitic (C-16, saturated).
4. Major sources of oils and fats are peanut (groundnut), mustard, soybean, sunflower, coconut, palm and milk.
5. Fats and oils belonging to oleic-linoleic acid group are the most abundant. They contain large amounts of oleic acid (C-18 mono unsaturated) and linoleic acid (C-18 diunsaturated) and less than 20% saturated fatty acids.
6. Important members of oleic-linoleic acid group are peanut, sunflower, cotton seed and sesame oils.
7. Milk fat is unique because it contains appreciable amounts of shorter chain acids (C-4 to C-12).
8. Animal fats contain appreciable amounts of fully saturated triacylgylcerols and exhibit relatively high melting points.

Check your progress Exercise 1

1. Define lipids and mention main sources of lipids.

----

2. What is role of food lipids in human diet?

   ----

3. Mention the major classes of lipids and describe acylglycerols.

   ----

4. Name the categories of fats and oils with examples.

   ----

5. What are the main differences between vegetable oil and animal fats?

Next, let us look at the functional properties of food lipids.

3.4 FUNCTIONAL PROPERTIES OF FOOD LIPIDS

Chemically, fats and oils, as you may already know by now, are a combination of glycerol and fatty acids. The glycerol molecule has three separate points, where a fatty acid molecule can be attached. Physically, fats and oils differ in that fats are solid and oils are liquid at room temperature. You learnt earlier that the different properties are to a large extent determined by the fatty acid composition and the extent of saturation or unsaturation present. These aspects are identified by the carbon chain length and the number and position of double bonds for the individual fatty acids and their position of the glycerol. Generally, solid fats indicated by a dominance of saturated fatty acids and liquid oils, are an evidence of a high level of unsaturated fatty acids.

Carbon chain lengths of fatty acds in edible oils and fats vary between 4 and 24 carbon atoms with up to three double bonds. The most prevalent saturated fatty acids are lauric (C-12:0), myristic (C-14:0), palmitic (C-16:0), stearic (C-18:0), arachidic (C-20:0), behenic (C-22:0) and lignoceric (C-24:0). The most important monounsaturated fatty acids are oleic (C-18:1) and erucic (C-22:1). The polyunsaturated fatty acids are linoleic (C-18:2) and linolenic (C-18:3).

Natural fats and oils vary widely in their physical properties even though they are composed of the same or similar fatty acids. These differences result from differences in the proportion of the fatty acids and the structure of the individual triglycerides. Factors that affect the properties of vegetable oil are plant maturity, plant health, microbiological, seed location within the flower and the genetic variation of the plant. Animal fats and oils composition varies according to the animal species, diet, health and fat location on the carcass and maturity.

Physical properties of an oil or fat are of critical importance in determining its functional characteristics or use in food products. One fundamental physical property of importance is demonstrated by the terms *fats* and *oils,* which indicate whether a lipid is a solid or liquid at ambient temperatures. But this grouping is not rigid because vegetable oils that are solid at ambient temperatures in a temperate climate are liquid at the tropical ambient temperatures. How then can one measure the functional properties? Have you come across the term performance testing? The next section presents a detailed discussion on this aspect.

3.4.1 Measurement of Functional Property

Fats and oils have several functional properties that affect the quality of processed foods. In deep fat frying, the roles played by the frying oil are many: These include:

1. It acts as an effective heat exchange medium leading to cooking of the product being fried and evaporation of water from the product,
2. It helps in the development of texture of fried food.

3. Oil absorbed by the products provides characteristic fried taste and flavour. In the preparation of the baked products, presence of fat contributes to texture and flavour. Fats and oils form emulsion in batters and doughs leading to the development of desirable structure and texture on baking or toasting.

Some essential attributes contributed by fats and oils cannot be directly measured with chemical or physical analytical methods. In these cases, *performance testing* is the only means for evaluating the ability of fat or oil to perform the desired functions in a food product. Actual determinations of the performance qualities of an edible fat and oil product are made with small scale practical tests that evaluate a finished product. *Performance testing is essential for the development of new products, especially for fats and oils products designed for a specific food product, a formulation, or a process.* After development, physical or chemical analysis can be related to performance results in most situations; however, continuation of certain performance evaluations is necessary for some products to ensure adequate performance or more timely results in some cases. Initially, most performance testing was designed for bakery products but has now been expanded to every specialty product situation, i.e., baking, frying, candy, coatings, formulated foods, nondairy products, and so forth, wherever tailored oils, margarines, oils and other specialty products are utilized. In many cases the performance tests are developed to evaluate the fat and oil ingredient as it would be used by a specific food processor. You would realize, performance evaluation in itself can be a detailed subject of study. Here, in this unit we shall not dwell on this aspect. Those of you, who are interested to learn more about performance evaluation, read box 1 for information. It provides a few examples of performance evaluation.

Box 1: Performance Evaluation, a few examples

Creaming volume – Cake batter aeration can be affected by the plasticity, consistency, emulsification, bake stock formulation and other fats and oil properties. *Creaming volume evaluations measure the ability of an oil or margarine to incorporate and retain air in a cake batter*. In most cases, batter aeration is an indicator of the baked cake volume, grain and texture and materially affects the handling qualities of the cake batter.

The creaming volume test formula consists of only three ingredients: (1) Test oil or margarine, (2) granulated sugar, and (3) whole eggs. This procedure is the first stage of an old fashion pound cake, where all of the cake batter aeration depended upon the creaming properties of the oil with whole eggs. Batter specific gravities are determined after mixing for 15 minutes and again after 20 minutes. Continued aeration, identified by a decrease in batter specific gravity, indicates that the fat or oil product has a stable consistency that has not broken down to allow the release of air from the batter. Specific gravity is expressed as grams per cubic centimeter per 100 grams, calculated by multiplying the reciprocal of the specific gravity by 100. Specific volume better illustrates the amount or degree of aeration. The performance test is applicable to emulsified, as well as non emulsified products, to measure aeration potential in a cake batter.

Pound cake test – In some cases, oil or margarine creaming volume is most accurately measured by preparing a regular pound cake, omitting the chemical leavener and measuring the volume, grain and texture of the baked cake. Creaming volume, as determined by this method, is affected by batter mixing temperature. Working range or creaming range can be measured by adjusting the finished batter temperature over the desired temperature range. The results obtained in this manner provide a good indication of the creaming range or oil temperature tolerance. The baked pound cake volume is determined by a seed displacement procedure and the cake appearance rated numerically with a scale similar to that provided in table 3.5.

Table 3.5: Rating Scale for Cake

Score	Rating	Description
10	Perfect	Fine regular grains; no holes, cracks, or tunnels; Very thin cell walls and perfect symmetry
9	Very Good	Close regular grain; free of holes, cracks or tunnels, may have occasional hole, good cell wall thickness
8	Good	Grain very slightly open but regular, free of cracks or tunnels, may have occasional hole, good cell

		wall thickness
7	Satisfactory	Grain slightly open, mostly regular, a few small holes, no tunnels or racks, slightly thick cell walls
6	Poor	Open or irregular grain, or frequent holes, some cracks or tunnels
5	Unsatisfactory	Very open or irregular grain, or numerous holes, cracks or tunnels, or thick heavy cell walls; may have solid strweaks or gum line
4 and below	Bad	Increasing degrees of unsatisfactory performance

Cake mix evaluation – Originally, cake mix formulations were very similar to bakery cakes and utilized standard "Hi-Ratio" cake oils; however, development of improved cake mixes required rapid aerating oils to minimize mixing times for the house wife, while at the same time increasing the product's mixing and baking tolerances. The competitive nature of the cake mix industry has continued the demands for new and improved products, of which oil has always been a major contributor. A basic white mix cake formulation and the make-up procedure can serve to evaluate new or revised emulsifier systems for aeration, eating qualities and cake shelf-life, as well as the oil carrier for lubrication and consistency.

Restaurant deep fat frying evaluation – A number of factors are studied when evaluating frying oils. During deep fat frying, the fat is exposed continuously to elevated temperatures in the presence of air and moisture. A number of chemical reactions, including oxidation and hydrolysis, occur during this time, as well as changes due to thermal decomposition. As these reactions proceed, the functional, sensory and nutritional quality of the frying fat changes and eventually reaches a point where it is no longer possible to prepare quality fried products and the fat will have to be discarded. The rate of frying fat deterioration varies with the food fried, the frying fat utilized, the fryer design and the operating conditions.

The deep fat frying evaluation consists of controlled heating of the test oils at 360±10°F (176 to 187°C) continuously until the test is terminated. Fresh French cut potatoes (227 grams) fried three times daily for 7 minutes at 3-hour interval are flavoured once daily.

Frying observations recorded after each frying includes smoking, odor, clarity, gum formation and a determination of foam development. Foam development described as none, trace, slight, definite and persistent should also be measured with a foam test daily and each time a change in the observed foam is recorded. Samples are taken after each 24-hour period for analysis of colour, free fatty acid and iodine value for quantitative measurement of darkening, hydrolysis and polymerization. The frying test is terminated when persistent foam has been observed and substantiated by foam height testing.

We have read about the deep fat frying evaluation method for measurement of functional properties of fat. Deep fat frying is commonly used as a cooking method in most homes. What are the issues to be considered while using this method of cooking is the focus of discussion in the next section.

3.5 DEEP FAT FRYING

Deep fat frying, as you may already know, is the method which involves cooking food in hot fat/oil. The fat immediately surrounds the food and cooks it from all sides, creating an exterior layer that seals in the food's flavors and juices inside. Deep frying is one of surest ways of locking in flavor and developing great texture (also known as "crunch") in cooking. Deep fat frying, in fact, has become one of the more important methods of food preparation used by the food service, snack and baking industries, as well as the home kitchen. The deep fat frying process consists most simply of (1) partially or totally immersing the food prepared for frying into (2) a body of heated frying fat, which is (3) contained in a metal vessel, and (4) maintaining the food in the fat at the appropriate frying temperature for (5) the duration required to cook the product. Going into the cooking utensil are (a) frying fat, (b) heat, and (c) the food prepared for frying. Emerging from the utensil are (a) steam and steam- entraining frying fat, (b) volatile by-products of heating and frying, (c) the finished product, and (d) with filtering, the crumbs or foreign solid by-products of the frying operation.

As you read the next section, you will realize all these factors mentioned above, have a role to play in the deep fat frying process. Let us get to know them.

3.5.1 Factors affecting the process of deep fat frying.

The common factors influencing the process of deep frying include:

1. *Heat*- Frying temperatures ranging from 150 –190°C are necessary to properly prepare the different fried food products. Unfortunately, exposure to high temperatures accelerates all of the breakdown reactions of fats and oils.
2. *Air*- Oxygen from the air is necessary to sustain human life, but it also reacts with the double bonds in the frying oils to oxidize the unsaturated fatty acids, which results in offensive odors and flavours and promotes gum formation or polymerization.
3. *Moisture*- All food products contain moisture, which causes hydrolysis of fats and oils, resulting in an increased fat absorption in most foods.
4. *Contamination*- Any material associated with the frying process that causes the frying media to deteriorate or accelerate the process is a contaminant. Some examples of frying fat contaminants are:
    - *Trace metals* – Most metals are pro-oxidants that exert a marked catalytic effect to accelerate fat breakdown, but some metals are much more active than others. These pro-oxidants can be picked up during processing or storage, from frying equipment, the food fried, or some other contact with a metal. Two metals that promote more rapid breakdown of frying than others are brass and copper.
    - *Soap or detergent*- Residue of these materials from cleaning storage tanks, fryers, or utensils which will catalyze fat breakdown.
    - *Gums or polymerized fats*- Addition of polymerized fats or oils to fresh oils act as catalysts to accelerate the formation of more gums, which contribute to foaming and darkening.
    - *Burnt food particles*- Food particles allowed to remain in the frying fat impart a bitter, caramelized and / or burnt taste along with an unappealing appearance to the food fried and accelerate frying oil breakdown.
5. *Time* – The extent of the frying oil's exposure to the effects of the above factors determines the degree of product deterioration.

So now you realize, the simple process of deep frying is not actually so simple. Utmost care needs to be taken while using this method to ensure that the quality of the frying oil is maintained. The next section is devoted to this crucial practical aspect i.e., maintaining the quality of fried oils.

3.5.2 Maintaining the quality of frying oil

As frying continues, the level of oil in the fryer depletes. There are two beneficial frying fat quality factors affected during the frying operation. These include:

- the steam released during frying, and
- the addition of fresh oil to replace the fat absorbed by the food fried.

Steam formed from the moisture released from the food mixes intimately with the fat, and when given off, it carries with it the odor- and flavour-bearing volatile by-products of frying that would otherwise accumulate in the frying fat to adversely affect the flavour and odor of the fried food. This steam continually scrubs or purges the frying fat of the potential off – flavours and odors each time the food is fried, even though it is the same moisture that causes hydrolysis. Fresh oil must be added to the fryer to compensate for the fat removed by the fried product. This addition helps to overcome the changes to the frying fat brought about by the heat and other frying fat enemies. Obviously, the frying fat will remain in better condition when higher replacement oil quantities are required. The ratio of the fryer's capacity to the rate at which the fresh oil is added to replenish the fryer is referred to as *turnover rate, or the number of hours required for the addition of fresh frying oil equal to the amount of fat maintained in the fryer*. Because oxidative changes occur continuously in heated fats, turnover must be related to the total period that the fat is heated, rather than only the actual time the product is fried. Obviously, the quality and, especially, the flavour of the frying fat will be maintained at a more desirable level with the highest turnover rate. In general, an operation with a turnover less than a day should never have to discard used frying oil because of breakdown, except in the case of product abuse or a contaminant. Operations with a slower turnover rates need to include this product quality and economic factor in their frying oil selection criteria.

Before we move on further, let us recapitulate what we have learnt so far. The salient points are listed in points to remember given herewith. Read them carefully.

POINTS TO REMEMBER

1. Natural fats and oils vary widely in their physical properties even though they are composed of the same or similar fatty acids.
2. Physical properties of a oil or a fat are of critical importance in determining its functional characteristics or use in food products.
3. Performance testing is the means for evaluating the fat or oil's ability to perform the desired functions in a food product.
4. Cake batter aeration can be affected by the plasticity, consistency, emulsification and other properties of fats and oil.
5. Deep fat frying has become one of the most important methods of food preparation.
6. Factors affecting the frying process are frying temperature, oxygen from air, moisture content of the food, duration of frying and presence of contaminants.
7. The rate of frying fat deterioration varies with the food fried, the frying fat utilized, the fryer design and the operating conditions.
8. Fresh oil must be added to the fryer to compensate for the fat removed by the fried product. This addition helps to overcome the changes in the frying fat.
9. Quality and flavour of the frying fat will be maintained at a desired level with the highest turnover rate.

Check your progress Exercise 2

1. Name the factors that affect physical properties of fats and oils.

----

2. Mention important functional properties of fats and oils

   ----

3. What are the salient features of performance test?

   ----

4. Name the factors affecting deep fat frying.

   ----

5. What is turnover rate of frying oil?

   ----

6. How does turn over rate affect the quality of frying oil?

3.6 DETERIORATIVE CHANGES IN FATS AND OILS

From our discussion so far it is clear that the food products undergo changes in flavour due to the chemical changes occurring in fats and oils present in them. The causative factors responsible for such changes are presence of enzymes, atmospheric oxygen and application of high temperature. Lipid oxidation is one of the major causes of food spoilage. It is of great economic concern to the food industry because it leads to the development of various off-flavours and off odours generally called ‘rancid’ (oxidative rancidity), in edible oils and fat-containing foods, which render these foods less acceptable. In addition, oxidative reactions can decrease the nutritional quality of food and certain oxidation products are potentially toxic. On the other hand, under certain conditions, a limited degree of lipid oxidation is sometimes desirable, as in aged cheeses and in some fried foods.

In this section we will look at the oxidative and other changes occurring in fats and oils causing deterioration. We begin with autoxidation.

3.6.1 Autoxidation

It is generally agreed that "autoxidation", that is, *the reaction with molecular oxygen via a self – catalytic mechanism*, is the main reaction involved in oxidative deterioration of lipids. Autoxidation reaction can be divided into three parts:

a. initiation,

b. propagation, and

c. termination.

In the initiation part, hydrogen is removed from the fatty acid chain to yield a free radical. The removal of hydrogen takes place at the carbon atom next to the double bond and can be brought about by the action of light, metals etc. Let us understand this concept with the help of an example. For example, in oleic acid, the reaction will proceed by removal of hydrogen from carbons 8 or 11 resulting in free radical as shown herewith.

$$COOH - (CH_2)_6 - \overset{8}{C}H_2 - \overset{9}{C}H = \overset{10}{C}H - \overset{11}{C}H_2 - (CH_2)_6 - CH_3$$

$$- \overset{8}{C}H - \overset{9}{C}H = \overset{10}{C}H - \overset{11}{C}H_2 - \qquad\qquad \overset{8}{C}H_2 - \overset{9}{C}H - \overset{10}{C}H = \overset{11}{C}H -$$

Generally, the reaction can be shown as:

$$RH \longrightarrow R' + H'$$

(R' is the free radical)

Once a free radical is formed, it will combine with oxygen to form a peroxy-free radical which can remove hydrogen from another unsaturated molecule who yield a peroxide and a new free radical. This is called ‘propagation reaction’, as illustrated herewith. This reaction may repeat upto several thousand times and has the nature of a chain reaction.

$$R'' + O_2 \longrightarrow RO_2$$
$$RO_2 + RH \longrightarrow ROOH + R'$$

The propagation can be followed by termination, if the free radicals react with themselves to yield non-active products:

$$R' + R' \longrightarrow R-R$$
$$R' + RO_2 \longrightarrow RO_2R$$
$$nRO_2' \longrightarrow (RO_2)_n$$

You must remember that the hydro peroxides (ROOH) formed in the propagation part of the reaction are the primary oxidation products. They are generally unstable and decompose into secondary oxidation products which include a variety of compounds. Among the secondary oxidation products, aldehydes and alcohols form an important group. The volatile aldehydes are mainly responsible for the oxidized flavour (rancid) of fats.

A general scheme summarizing the overall picture of lipid autoxidation is given in the figure 3.1.

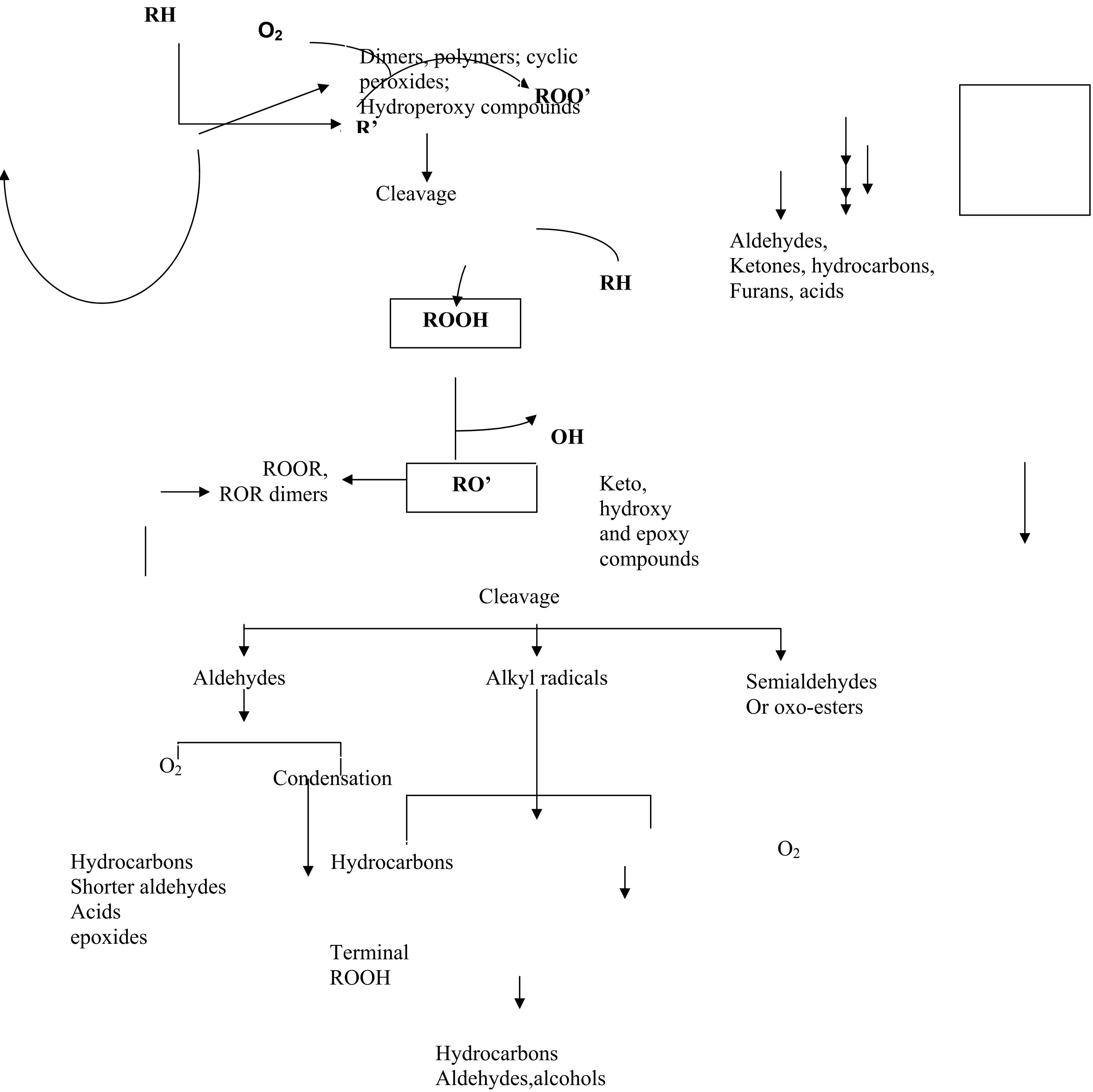

RH
O2
Dimers, polymers; cyclic
peroxides;
Hydroperoxy compounds
ROO'
R'
Cleavage
Aldehydes,
Ketones, hydrocarbons,
Furans, acids
RH
ROOH
OH
ROOR,
ROR dimers
RO'
Keto,
hydroxy
and epoxy
compounds
Cleavage
Aldehydes
Alkyl radicals
Semialdehydes
Or oxo-esters
O2
Condensation
O2
Hydrocarbons
Shorter aldehydes
Acids
epoxides
Hydrocarbons
Terminal
ROOH
Hydrocarbons
Aldehydes,alcohols

Figure 3.1:Generalised scheme for autoxidation of lipids

There are many factors influencing the lipid autoxidation process you have just learnt about. Let us get to know them.

3.6.2 Factors Influencing Lipid Oxidation

Food lipids contain a variety of fatty acids that differ in chemical and physical properties and also in their susceptibility to oxidation. In addition, foods contain numerous non lipid components that may co-oxidize and / or interact with the oxidizing lipids and their oxidation products. Oxygen concentration, temperature and moisture are the other factors influencing autoxidation. Let us learn how.

- *Fatty acid composition*

  We know fats/oils are made up of fatty acids. The number, position and geometry of double bonds within the fatty acids affect the rate of oxidation. Relative rates of oxidation for arachidonic, linolenic, linoleic and oleic acids are approximately 40:20:10:1, respectively. Cis acids oxidize more than their trans-isomers, and conjugated double bonds are more reactive than nonconjugated. Autoxidation of saturated fatty acids is extremely slow. At room temperature, they remain practically unchanged when oxidative rancidity of unsaturates becomes detectable. At high temperatures, however, saturated acids can undergo oxidation at significant rates.

- *Oxygen concentration*

  When oxygen is abundant, the rate of oxidation is independent of oxygen concentration, but at very low oxygen concentration, the rate is approximately proportional to oxygen concentration. However, the effect of oxygen concentration on rate is also influenced by other factors, such as temperature and surface area.

- *Temperature*

  In general, the rate of oxidation increases as the temperature is increased. Temperature also influences the relation between rate and oxygen partial pressure. As the temperature is increased, changes in oxygen partial pressure have a smaller influence on the rate because oxygen becomes less soluble in lipids and water, as the temperature is raised.

- *Surface area*

The rate of oxidation increases in direct proportion to the surface area of the lipid exposed to air. Furthermore, as surface – volume ratio is increased; a given reduction in oxygen partial pressure becomes less effective in decreasing the rate of oxidation. In oil-in-water emulsions, the rate of oxidation is governed by the rate at which oxygen diffuses into the oil phase.

- *Moisture*

In model lipid systems and various fat-containing foods, the rate of oxidation depends strongly on water activity. In dried foods with very low moisture contents (a_w values of less than about 0.1), oxidation proceeds very rapidly. Increasing the a_w to about 0.3 retards lipid oxidation and often produces a minimum rate. The protective effect of small amounts of water is believed to occur by reducing the catalytic activity of metal catalysts, by quenching free radicals and / or by impeding access of oxygen to the lipid.

At somewhat higher water activities (a_w = 0.55 – 0.85), the rate of oxidation increases again, presumably as a result of increased mobilization of catalysts and oxygen.

- *Pro-Oxidants*

Transition metals, particularly those possessing two or more valency states and a suitable oxidation – reduction potential between them (e.g., cobalt, copper, iron, manganese and nickel), are effective pro-oxidants. If present, even at concentrations as low as 0.1 ppm, they can decrease the induction period and increase the rate of oxidation. Trace amounts of heavy metals are commonly encountered in edible oils and they originate from the soil in which the oil – bearing plant was grown, from the animal, or from metallic equipment used in processing or storage. Trace metals are also naturally occurring components of all food tissues and of all fluid foods of biological origin (eggs, milk, and fruit juices) and are present in both free and bound forms.

After autoxidation, we look at the deteriorative changes caused by lipolysis.

3.6.3 Lipolysis

What do we mean by lipolysis? *Hydrolysis of ester bonds in lipids is called lipolysis*. This may occur by enzyme action or by heat and moisture, resulting in the liberation of free fatty acids. Free fatty acids are virtually absent in the fat of living animal tissue. These can be formed, however, by enzyme action after the animal is killed. Since animal fats are not usually refined, prompt rendering is of particular importance. The temperatures commonly used in the rendering process are capable of inactivating the enzymes responsible for hydrolysis. In contrast to animal fats, oils in mature oil seeds may have undergone a substantial hydrolysis by the time they have harvested, giving rise to significant amounts of free fatty acids. Neutralization with alkali is thus required for most vegetable oils after they are extracted.

Lipolysis is a major action occurring during deep fat frying due to large amounts of water introduced from the food and the relatively high temperatures used. Development of high level free fatty acids during frying is usually associated with foaming and a decrease in the smoke point of the oil and reduction in the quality of the fried food. The release of short – chain fatty acids by hydrolysis is responsible for the development of an undesirable rancid flavour (hydrolytic rancidity) in raw milk. Furthermore, free fatty acids are more susceptible to oxidation than other fatty acids esterified to glycerol.

Lipolysis, therefore, can cause changes in fats and oils which are best avoidable. On the other hand, you would be surprised to learn that certain typical cheese flavours are produced by deliberate action of microbial and milk lipases. Controlled and selective lipolysis is also used in the manufacture of other food items, such as yogurt and bread.

Besides lipolysis, thermal decomposition too can bring about changes in oils and fats which are deteriorative. Let us learn about these changes.

3.6.4 Thermal Decomposition

Heating of food produces various chemical changes, some of which can be important to flavour, appearance, nutritive value and toxicity. Not only do the different nutrients in food undergo decomposition reactions, but these nutrients also interact among themselves in extremely complex ways to form a very large number of new compounds.

The chemistry of lipid oxidation at high temperatures is complicated by the fact that both thermolytic and oxidative reactions are simultaneously involved. Both saturated and unsaturated fatty acids undergo chemical decomposition when exposed to heat in the presence of oxygen. A schematic summary of these mechanisms is shown in figure 3.2.

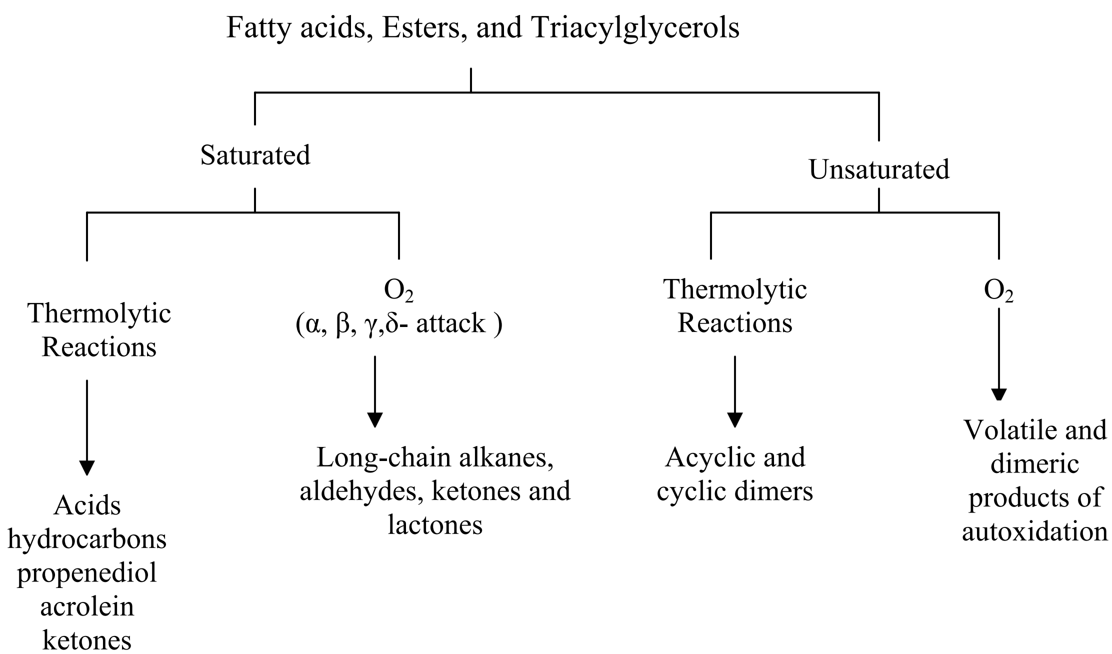


Figure 3.2: Thermal Decomposition of Fats and Oils

With thermal decomposition, we complete our study on the deteriorative changes in fats and oils. Now, the next important issue is how to prevent these deteriorative changes? The answer lies in one word 'Antioxidants'. Let us learn about what the antioxidants are and how they play a protective role in the context of fats and oils.

3.7 ANTIOXIDANTS

Antioxidants are the substances that can delay onset, or slow the rate of oxidation of autoxidizable materials. By virtue of this property, they provide protection against oxidative changes in fats and oils. They act by reacting with the free radicals and thereby terminate the propagation of chain reaction. The antioxidant reacts with the fatty acid free radical or with the peroxy free radical. Literally hundreds of compounds, both natural (including vitamins C and E, vitamin A, selenium (a mineral) and a group known as the carotenoids) and synthesized, have been reported to possess antioxidant properties. Their use in foods, however, is limited by certain obvious requirements not the least of which is adequate proof of safety. The main lipid soluble antioxidants currently used in food are monohydric or polyhydric phenols with various ring substitutions. For maximum efficiency, primary antioxidants are often used in combination with other phenolic antioxidants or with various metal sequestering agents.

Although the mechanisms by which many antioxidants impart stability to pure oils are relatively well known, much remains to be learned about their action in complex foods. Some commonly used/present antioxidants in fats and oils and their characteristics are discussed herewith.

Characteristics of Some Commonly Used Primary Antioxidants:

- *Tocopherols:* These are the most widely distributed antioxidants in nature, and they constitute the principal antioxidants in vegetable oils. A relatively high proportion of the tocopherols present in crude vegetable oils survives the oil processing steps and remains in sufficient quantities to provide oxidative stability in the finished product.
- *Butylated hydroxyanisole (BHA):* It is commercially available as a mixture of two isomers and has found wide commercial use in the food industry. It is highly soluble in oil and exhibits weak antioxidant activity in vegetable oils, particularly those rich in natural antioxidants. BHA is relatively effective when used in combination with other primary antioxidants. BHA has a typical phenolic odor that may become noticeable if the oil is subjected to high heat.

- *Tertiary Butylhydroquinone (TBHQ):* TBHQ is moderately soluble in oil and slightly soluble in water. In many cases, TBHQ is more effective than any other antioxidant in providing oxidative stability to crude and refined polyunsaturated oils, without problem of colour or flavour stability. TBHQ is also reported to exhibit good carry - through characteristics in the frying of potato chips.

POINTS TO REMEMBER

1. Lipid oxidation is one of the major causes of food spoilage. It leads to the development of off flavours and off odours generally called rancid.
2. Autoxidation is the reaction of fats and oils with molecular oxygen. It consists of three steps namely, initiation, propagation and termination.
3. Volatile aldehydes formed during autoxidation are mainly responsible for the rancid flavour of fats and oils.
4. The number, position and geometry of double bonds in the fatty acid chain affect the rate of oxidation. As the number of double bonds increase, there is an increase in the rate of oxidation.
5. Oxygen concentration, temperature, surface area of the lipid exposed to air and moisture content influence the lipid oxidation.
6. Hydrolysis of ester bonds in lipids can occur by enzyme action, heat and moisture, resulting in the liberation of free fatty acids.
7. Development of high level of free fatty acids during frying is associated with a decrease in smoke point and reduction in the quality of fried food.
8. Lipid oxidation at high temperature involves both thermolytic and oxidative reactions leading to loss of flavour, appearance and nutritive value.
9. Antioxidants can delay the onset, or slow the rate of oxidation of fats and oils.

Check your progress Exercise 3

1. What is autoxidation and mention the three steps involved in it?

----

2. What is rancidity? Mention the compounds responsible for it.

----

3. List the factors influencing lipid oxidation.

----

4. Define lipolysis and name the compound liberated by it.

----

5. List the compounds formed by the thermal decomposition of fats and oils.

----

6. How antioxidants delay the onset of rancidity?

----

7. Name some commonly used antioxidants.

3.8 LET US SUM UP

Lipids are the major components of oil bearing materials and adipose tissue. They consist of broad group of compounds that are generally soluble in organic solvents. Largest source of vegetable oil is the seeds of plants such as peanut, sunflower, cottonseed, mustard and safflower. Acylglycerols or glycerol esters of fatty acids which make upto 99% of the lipids of plant and animal origin have been traditionally called fats and oils. Oils of vegetable origin contain large amounts of oleic and linoleic acid. Physical and chemical properties of oils and fats are important to their functional properties in many foods. Many essential attributes contributed by fats and oils can be evaluated by conducting performance tests. These tests are designed for products such as baked goods, candy, coating snacks and formulated products. Deep fat frying is an important method of food preparation. Factors affecting the process of deep fat frying are frying temperature, exposure to air, moisture content of the food being fried, presence of contaminants such as trace metals, soap or detergent and duration of heating. Fats and oils undergo changes in flavour or they develop rancid flavour due to the presence of enzymes, atmospheric oxygen and application of high temperature. Autoxidation is the main reaction involved in the oxidative deterioration of lipids. Autoxidation occurs through free radical mechanism consisting of three steps, namely, initiation, propagation and termination. Lipid oxidation is influenced by the fatty acid composition, oxygen concentration, temperature, surface area, moisture and pro-oxidants. Lipolysis is the hydrolysis of the ester bonds in the lipids resulting in the liberation of free fatty acids which are more susceptible to oxidation than acylglycerols. Lipids undergo chemical decomposition when exposed to heat in presence of oxygen. Antioxidants are the substances that can delay the onset or slow the rate of oxidatioin of lipids. The main antioxidants used in food are monohydric or polyhydric phenols with various ring substitutes. Tocopherols are the most widely distributed natural antioxidants in vegetable oils. Tertiary butyl hydroquinone (TBHQ) is more effective than any other antioxidant in providing oxidative stability to oils and fats.

3.9 GLOSSARY

Acylglycerols : Most abundant; these constitute upto 99% of the lipids of plant and animal origin. They are esters of fatty acids with glycerol.

Antioxidants : Substances that can delay the onset, or slow the rate of oxidative deterioration of oils and fats.

Autoxidation : Reaction of the molecular oxygen with oils and fats leading to the development of off odour or rancidity.

Cis-trans isomers : Atoms or groups are called *cis* or *trans* to one another when they project respectively on the same or on opposite sides of a reference plane identifiable as common among stereoisomers. The compounds in which such relations occur are termed *cis/trans*-isomers.

Fatty acids : Aliphatic monocarboxylic acids that can be liberated by hydrolysis from naturally occurring fats and oils.

Functional property : Properties of fats and oils which have a marked influence on the preparation and quality of a food product.

Lipids : Broad group of compounds that constitute the principal structural components of all living cells, and are generally soluble in organic solvents.

Lipolysis : Hydrolysis of ester bond in lipid caused by enzyme action, heat and moisture resulting in liberation of free fatty acids.

Oleic – linoleic group : Most abundant group of fats and oils that contain large amounts of oleic and linoleic acid.

Oxidation-reduction Potential (ORP) : ORP is related to the concentration of oxidizers or reducers in a solution, and their activity or strength. It provides an indication of the solution's ability to oxidize or reduce another material. These chemicals have the ability to oxidize (accept electrons) or reduce (donate electrons) molecules.

Performance test : A method for evaluating the ability of fat or oil to perform the desired functions in a food product.

Pro-oxidants : Transition metals, possessing two or more valency states and a suitable oxidation-reduction potential between them.

Rancidity : Development of-off flavour in fats and oils caused by autoxidation, lipolysis or thermal decomposition.

Thermal Decomposition : Chemical decomposition of oils and fats when exposed to heat in the presence of oxygen.

3.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Lipids are a broad group of compounds those are generally soluble in organic solvents but sparingly soluble in water. Main sources of lipids are oil bearing nuts, seeds and fruits. Example peanuts, sunflower, mustard and soyabean.

2. The role of food lipids in human diet are follows: lipids supply calories, essential fatty acids, act as fat-soluble vitamin carriers and increase the palatability of food.

3. The major classes of lipids are simple lipids (acylglycerols and waxes); Compound lipids (glycerophospholipids); Derived lipids (compounds that are not simple or compound lipids) example, Carotenoids and vitamins. Acylglycerols are the glycerol esters of fatty acids which make up to 99% of the lipids of plant and animal origin.

4. Milk fats Example: Cow and Buffalo milk;
   Lauric acid group Example: Coconut oil;
   Vegetable butters Example: Cocoa butter;
   Oleic linoleic acid group Example: Peanut, cotton seed, sunflower oils;

Linolenic acid group Example: Soyabean, Mustard;

Animal fats Example: Lard, tallow

Check Your Progress Exercise 2

1. The factors that affect physical properties of fats and oils are fatty acid composition, degree of unsaturation and structure of individual triglycerides.

2. The important functional properties of fats and oils are discussed as follows. Frying oil is an effective heat exchange medium, to help in development of texture and flavour of fried foods. Form emulsions in batter and dough. Contribute to the texture and flavour of baked products.

3. The salient features of performance test are that it helps in evaluating the ability of fat and oil to perform the desired function in a food product. It is essential for the development of specific food products and formulations.

4. The factors affecting deep fat frying are temperature of frying; presence of oxygen; moisture content of food; presence of contaminants such as trace metals and duration of frying

5. Number of hours required for the addition of fresh frying oil equal to the amount of oil maintained in the fryer is referred to as the turnover rate of frying oil.

6. The turn over rate affects the quality of frying oil by maintaining the flavour at a more desirable level, slowing down oxidative changes occurring in frying fat and minimizing discard of used frying oil.

Check Your Progress Exercise 3

1. Reaction of fats and oils with molecular oxygen by means of a self catalytic mechanism is referred to as autooxidation. The three steps involved are initiation, propagation and termination.

2. Off flavours caused by the chemical changes occurring in fats and oils is referred to as rancidity. The compounds responsible for it are unsaturated aldehydes, ketones, alcohols and acids.

3. The factors influencing lipid oxidation are fatty acid composition, oxygen concentration, temperature, surface area of the lipid, moisture and the presence of pro-oxidants.

4. Lipolysis is the hydrolysis of ester bonds in lipids caused by the action of enzyme, heat or moisture. Free fatty acids are liberated as a result of lipolysis.

5. The compounds formed by the thermal decomposition of fats and oils are acyclic and cyclic dimers, long-chain alkanes, aldehydes, ketones and lactones and hydrocarbons.

6. Antioxidants delay the onset of rancidity by reacting with the fatty acid free radical or with the peroxy free radical and thereby terminate the chain reaction of lipid oxidation.

7. Some commonly used antioxidants are Tocopherols, Butylatedhydroxyanisole and tertiary Butylhydroquinone.

UNIT-4 PROTEINS

Structure

4.1 INTRODUCTION

Like carbohydrates and fats, proteins are essential to us in an incredible variety of different ways. Proteins are complex macromolecules, which constitute 50% or more of the dry weight of living cells. Muscle, ligament, cartilage, skin, hair etc. are mainly protein material. What are proteins? What is their composition, properties and functional applications in our food? These issues are discussed in this unit. The detailed structure and properties of proteins and amino acids are discussed in the Nutritional Biochemistry course, Block 1, unit 1. The functions, particularly the biological functions of proteins are dealt with in the Advance

Nutrition Course, block 1, unit 4. We suggest you to look at the structure, properties and functions of protein there before you move on to this unit. You will find a comprehensive review on the functionality of proteins in this unit, which as a food scientist, you will find quite useful.

Objectives

After studying this unit, you will be able to:

- discuss the composition and classification of proteins,
- enumerate the properties of amino acids and proteins, and
- understand the applications of protein concentrates, isolates and hydrolysates.

4.2 PROTEINS – CLASSIFICATION, COMPOSITION AND BIOLOGICAL FUNCTIONS

Proteins, as you may already know, are made up of carbon, hydrogen, nitrogen, oxygen and usually sulphur. Proteins are built up of a large number of amino acid molecules inter linked by peptide bonds as illustrated in figure 4.1. All the amino acids have a trivial or common name, many a times is related to the source from which they have been first isolated. For example:

Trivial Name of Protein	**Source**
Asparagine	Asparagus
Glutamine	Wheat gluten
Tyrosine	Cheese (*Tyros* is the *Greek word for cheese)*
Glycine- sweet taste (*Glykos* is the *Greek word for sweet)*	

Amino acids are twenty in number, and you have read in the Nutritional Biochemistry Course that they are classified according to the nature of the side chain (R group). We shall not go into the classification and composition of amino acids here. This has been discussed in details in Unit 2 of the Nutritional Biochemistry Course. Look up the relevant section before you proceed further.

Figure 4.1: Peptide bond formation between two amino acids with the elimination of water

Let us look at the classification, composition and biological functions of proteins next. We start with the classification.

4.2.1 Classification of Proteins

You may recall reading earlier about the classification of proteins in the Nutritional Biochemistry Course, Unit 2 and also in the Advance Nutrition Course, Unit 4. Let us review the classification here again. Box 4.1 summarizes the classification of proteins.

Box 4.1: Classification of Proteins

Proteins can be classified based on:

Shape and size	Functional properties	Solubility and physical properties
• Fibrous proteins for example: keratin in hair, actin and myosin in muscles, and collagen. • Globular proteins, for example enzymes and antibodies.	• Immunoproteins such as C-reactive protein, Opsonin Immunoglobulins, • Contractile • respiratory, • structural, • enzymatic, • hormonal • carrier proteins	• Simple proteins • Conjugated proteins • Derived proteins

As can be seen in box 4.1, proteins can be classified based on:

I *Shape and size*: fibrous proteins and globular proteins. Fibrous proteins play structural roles in organisms. Globular proteins consist of long chains of amino acids folded up into complex shapes.

II *Functional properties*: Immuno, contractile, respiratory, structural, enzymatic, hormonal and carrier proteins.

III *Solubility and physical properties*: Simple, conjugated and derived proteins. Table 4.1 enumerates this classification.

Table 4.1 Classification of proteins based on the solubility and physical properties

Simple Proteins	Conjugated Proteins	Derived Proteins
Simple proteins are those which are made of amino acid units only joined by peptide bond. Upon hydrolysis they yield a mixture of amino acids and nothing else. *Examples*: ***Albumins****:* Egg albumin, serum albumin, Lactalbumin *Globulin:* Tissue globulin, serum globulin. *Gliadins:* Wheat gliadin, hordein (barley) etc. *Albuminoids:* Keratin of hairs, skin, egg shell and bones, elastin, Collagen of tendons, ligaments and bones. *Histones:* globin of haemoglobin. *Protamine*: Salmine, the spermatozoa of salmon fish.	Conjugated proteins are composed of simple proteins combined with a non-proteinous substance. The non-proteinous substance is called prosthetic group or cofactor. *Examples:* *Chromoproteins:* Haemoglobin, in which the prosthetic group is iron. *Phosphoproteins*: casein in milk, in which prosthetic group is phosphoric acid, vitellin in egg yolk. *Lipoproteins:* HDL (high density lipoprotein), LDL (low density lipoprotein) and VLDL (very low density lipoproteins), the prosthetic group is lipid *Glycoprotein*: Ovomucoid of egg white. *Nucleoproteins:* ribosomes and viruses. *Metalloproteins:* alcohol dehydrogenase, a Zn containing enzyme. *Mucoproteins:* Follicle stimulating hormone, β-ovomucoid.	These are not naturally occurring proteins and are obtained from simple proteins by the action of enzymes and chemical agents, heat, mechanical shaking, UV or X-Rays. *Examples:* Primary, Myosin, Fibrin, Secondary, Peptones, peptides, proteoses etc.

Along with the classification, let us also quickly recapitulate the functions of proteins in our body. You may recall studying the functions of proteins in the Advance Nutrition course, block 1, unit 5. The next section summarizes the biological functions of proteins.

4.2.1 Biological Functions of Proteins

Proteins have roles in the structural and functional aspects of the cells and organelles. Proteins may be classified according to the following plan:

a. Structural elements: Structural proteins are fibrous proteins. The most familiar of the fibrous proteins are probably the *keratins*, which form the protective covering of all land vertebrates: skin, fur, hair, wool, claws, nails, hooves, horns, scales, beaks and feathers. Equally widespread, if less visible, are the *actin* and *myosin* proteins of muscle tissue. Structural proteins are very important for support. *Collagen* and *elastin* provide a fibrous framework in animal connective tissues, such as tendons and ligaments.

b. Defensive Proteins: These proteins protect against diseases. Antibodies are the example of defensive proteins. These combat bacteria and viruses. Also, immunoglobulins, as you are already aware, provide defense to body against invading organisms and infections.

c. Contractile Proteins: These proteins participate in contractile processes such as *muscle proteins* as well as those found in other cells and tissues. In the latter, these proteins participate in localized contractile events in the cytoplasm, in motile activity, and in cell aggregation phenomena. The examples of contractile proteins include *actin, myosin, myoglobin, troponin* etc. Actin and myosin are responsible for the movement of muscles. Contractile proteins are responsible for the undulations of cilia and flagella, which propel many cells.

d. Nutrient and Storage proteins: These proteins store amino acids. *Ovalbumin* is the protein of egg white, used as an amino acid source for the developing embryo. *Casein*, the protein of milk, is the major source of amino acids for baby mammals. Plants store proteins in seeds.

e. Transport proteins in plasma: Transport proteins, embedded in lipid membranes, facilitate the import of nutrients into cells or the release of toxic products into the surrounding medium. Molecules which cannot move across the membrane by diffusion must cross the membrane with the help of transport proteins. As carriers of plasma, these bind to small molecules and ions and transport them throughout the body. Few common examples include:

- An iron-binding protein (*transferrin*) delivers ferrous ions to hemoglobin synthesizing loci.
- Activity of ions, such as calcium, can be controlled by the ratio of free to bound species.

- When hydrogen ions are bound, proteins act as *buffers* to minimize the change in pH.
- Since cells are impermeable to proteins, they also participate in determining the distribution of ions and hence electrical potential difference across the cell membrane.
- By virtue of osmotic activity, albumins mediate the distribution of body fluids between plasma and extracelluar compartments

f. Enzymatic Proteins: The most varied and most highly specialized proteins are those with catalytic activity - *the enzymes*. Virtually all the chemical reactions of organic biomolecules in cells, you might be aware, are catalyzed by enzymes. More than 2,000 enzymes are known. Special class of enzymes fulfills a *mechanochemical role,* for example *actin, myosin and related proteins* of muscle structure are responsible for the conversion of chemical energy into mechanical work.

g. Hormonal proteins: Hormonal proteins coordinate the bodily activities. Various peptide and protein hormones (such as insulin and growth hormone) carry information that regulates cell permeability and cell metabolism.

h. Receptor Proteins: These are built into the membrane of a nerve cell and they detect chemical signals released by other nerve cells. Receptor proteins are involved in the cell's response to chemical stimuli.

i. Miscellaneous Functions:

Besides the functions enumerated above certain other important miscellaneous functions of proteins are included herewith. These include:

- Source of energy: Constituent amino acids can be deaminated and metabolized to carbon dioxide and water.
- Toxic proteins (for humans - botulinum toxin, staphylococcal toxin, venom toxin; for microorganisms - antibiotics)
- Anti-nutritional factors (trypsin inhibitors).
- Many allergic reactions to food are also mediated by proteins, which result in the modification of defence mechanism of consumer due to the presence of proteinaceous antigens in foods that promote antibody synthesis.

- Intense sweeteners (Monellin).

4.2.2 Composition of Proteins

We know that the amino acids are the building blocks of proteins. Amino acids are linked to one another by peptide bond formed by the elimination of a water molecule as illustrated in figure 4.1. Considering the long peptide chains and variation in the structure of twenty different amino acids, protein structure is divided into 4 different levels as illustrated in Table 4.1. The details related to the structure of each of these different proteins are included in the Nutritional Biochemistry Course (block 1, unit 1). Read the matter given there for comprehensive understanding of the protein structure.

Table 4.1: Different levels of protein structure

Primary structure	The primary structure of a protein consists of the order in which amino acids are bonded to one another by a peptide bond.
Secondary structure	The secondary structure of a protein involves the way that the chain of amino acid either twists or folds back upon itself to form alpha helical, beta sheet or a variety of other possible arrangements.
Tertiary structure	Secondary structure, in turn, folds back and bonds to itself in a three-dimensional manner.
Quaternary structure	When the protein consists of more than one chain, or the shape in which those separate chains bond together.

Besides the classification and composition of proteins, we would also spend some time recalling the food sources of proteins. We bet the protein food sources must be on your finger tips by now. Put them down and tally your responses with the sources given in the next section.

4.2.3 Food Sources of Proteins

Food protein sources can be divided into 3 major categories:

a. Protein of Animal Origin
b. Protein of Plant Origin
c. Single cell protein

Let us review these food sources one by one.

a) Proteins of Animal Origin

What are the foods of animal origin which can be classified as rich sources of proteins? You may already know, however, we have enumerated these sources herewith, for your perusal.

1. Meat: Skeletal or striated muscles are used for food purposes. Flesh of cattle, sheep and swine comprise most of the meat contents. Edible meat from these is designated as "Red Meat", a term descriptive of colors of beef, lamb or pork, as opposed to the light and dark colors of poultry meat. The red color is primarily due to myoglobin.

A typical adult mammalian muscle stripped of all external fat contains about 18-22% proteins on wet weight basis. Muscle proteins can be categorized on the basis of their origin and solubility as sarcoplasmic, contractile (myofibrillar) or stroma (connective tissue) proteins.

2. Milk: A value of 3.5% protein is often considered as an average for milk. Milk protein has traditionally been divided into 2 classes – casein and whey protein. Casein is a heterogenous group of phosphoprotein, which can be precipitated from raw skimmed milk by acidification at pI.14.6 and 20^{0}C. Proteins remaining in solution after casein precipitation are called 'whey proteins' (or milk serum proteins). Casein fraction consists of about 80% of total protein content, rest is whey protein. Whey fraction mainly consists of β-lactalbumin, α-lactalbumin, immunoglobulins, bovine serum albumin etc.

3. Eggs: Roughly, the chicken egg consists of 11% shell, 31% yolk and 58% white. Liquid whole egg consists of 65% white and 35% yolk. The primary function of egg protein is to nourish the young chick and provide food. Yolk appears to be the initial source of food, while egg white seems to act as a protective barrier, prior to its eventual use as a source of protein. Fundamentally, the white and yolk differ in their composition.

- *Yolk:* Yolk contains about 50% solids, of which $2/3^{rd}$ are lipids and proteins. On wet weight basis, egg yolk contains 31% fat, of which 1.3% is cholesterol.
- ***White****:* Essentially an aqueous solution containing about 12% proteins.

4. Fish: The edible portion is skeletal muscles of the body. Even though the skeletal muscles of different animals are basically similar, fish species used for food are far more numerous and diverse than the mammalian species.

Fish usually contains 40-60% edible flesh. Protein content of fresh water fish ranges from 13-25%. In the mid or lateral line of many fishes, there exists a layer of heavily pigmented reddish brown muscle that may contribute to 10% of total body muscle. This contains a high content of hemoprotein, which following the harvest, may catalyze oxidation of lipids and cause pronounced rancidity. The proteins may be classified as sarcoplasmic, myofibrillar or connective tissue protein.

5. Shell Fish: Information on shellfish is fragmentary and incomplete. In shell fish, the shell comprises of a large portion of live weight of the fish and thus their edible content is low. Eg. of shellfish are crabs, lobsters, prawns and muscle oysters etc.

Next, we shall study about the proteins of plant origin.

b) Proteins of Plant Origin

Vegetable proteins, cereal proteins, nuts and seed proteins come from the plant origin. Let us get to know more about these sources.

1. Vegetable Proteins: Fresh vegetables are not considered to be a very good source of proteins. On fresh weight basis, the average protein content of some common vegetables are carrots and lettuce – 1%, white potatoes, asparagus and green beans - 2% and fresh peas – 6%.

Although protein content of potatoes is only 2%, quality is considered to be good to excellent due to relatively high content of the amino acids – lysine and tryptophan. Outer layers, the so called “cortex” of tubers contain most of the proteins. These layers also have a much higher content of essential amino acids than do the inner layers. The outer layer proteins can be increased by selective plant breeding.

2. Cereal Proteins: Cereal grains, properly ripened and dried for optimum storage stability, have protein content ranging from 6-20%. Proteins are found in various morphological tissues of different grains. In the milling of grain (eg. wheat), the endosperm is essentially separated from the bran and germ and then pulverized to produce flour, which is used as food. Endosperm proteins apparently act as a structural component and also as food reserves for the growing seedlings. Much of the endosperm storage proteins in kernel of several cereal proteins are located in the sub-cellular granules or organelles known as 'protein bodies' (except in wheat kernel).

Bran or seed coat protein provides structure and protection to kernel. Since bran is so poorly digested by humans and the proteins are difficult to separate, most of the material is used for animal feed.

3. Seed Proteins: Although a large number of plants produce seeds having protein contents in excess of 15%, only a few are utilized for food, eg. soybean, cotton seeds, peas, peanuts and beans. Proteins of seeds are largely concentrated in protein bodies. These bodies, which have more than 90% proteins accounts for 70% of the total proteins in case of soybeans.

Proteins comprise a significant portion of food reserves, which is so important during germination. Proteins of most seeds (excluding cereals) are globulins, which are soluble in water or dilute salt solutions.

4. Nuts: Nuts are excellent sources of proteins. Examples of nuts include cashew nuts, almond nuts , hazel nuts , coconuts, walnuts, brazil nuts ,cashew nuts, pistachio nuts etc. Some nuts like almonds contain complete proteins.Those nuts that do not contain complete proteins can be extremely useful sources of proteins if they are eaten in combination with other protein foods, or with milk or cheese, or with vegetables.

Having studied about the proteins of plant origin we shall move on to study about proteins obtained from the microbial origin.

c) Single Cell Proteins (SCP)

You may have heard of SCP. What is a single cell protein? Let's find out.

The term SCP was coined by Prof. Caroll Wilson (MIT) in 1966. It means the proteins obtained from microbial sources, i.e. algae, fungi, bacteria, yeast etc. The proteins are isolated from microorganisms. Some of the advantages of selecting microorganisms as a source of protein are as follows:

a. High yield of proteins on dry weight basis.
b. Nutritional requirement is cost effective.
c. Less area is required for the installation of plant for the production of proteins as compared to the classical sources.
d. The plant may be designed in such a way that the processing can be done on a continuous basis instead of batch to batch basis.

For single cell proteins, bacteria, yeast, fungi and algae may be used. Each of them has their own advantages and disadvantages. These have been highlighted in Table 4.2. Another interesting aspect which you would surely like to know about is how these single cell proteins are manufactured. You will find information regarding the process in Box 4.2 herewith. This is some additional information for your knowledge.

Table 4.2: Advantages and disadvantages of using microorganisms as a source of protein

Organisms	Advantages	Disadvantages
Bacteria	• High yield of protein (60-80%) • Can be grown on paraffin, cellulose waste and molasses. • Growth rate is fast.	• If the bacterial strain is very small in size and of low density, separation from the culture media is difficult. • Bacteria have a high nucleic acid content (>15%) and may come over along with proteins, which is not acceptable and not required as it can cause hypertension, arthritis etc. • Uric acid, the final product of purine metabolism, may lead to gout.
Yeast	• Large size, hence separation from the culture medium is easy. • As the pH of the growth is towards acidic side, high amount of lysine is produced in the proteins, hence protein is more acceptable and of higher biological	• Less protein yield (45-60%) • Growth rate is low (1-3 h) • High nucleic acid content leading to the formation of uric acid.

	value.	
Fungi	• Easy to harvest from culture medium. • Texture of the fungi improves the functional properties of proteins.	• Less protein yield (5-27%). • Low growth rate. • Poor acceptability of proteins.
Algae	• Produces proteins which have almost all the Essential Amino acids. • Rich in tyrosine and serine, low in sulphur containing amino acids.	• If the more than 100 gm of proteins are consumed, it may cause nausea, vomiting, abdominal pain etc. because of the cellulosic cell wall, which is not digestible in human subjects.

Check Your Progress Exercise 1

1. How can proteins be classified? Give suitable examples.

   ----

2. Mention any two important functions of proteins in biological systems.

   ----

3. What are the 3 categories in which food protein sources can be divided into?

   ----

4. What is a single cell protein? Also, discuss some of the advantages of selecting microorganisms as a source of protein.

   ----

5. Fill in the blanks:

a) The proteins made up of only amino acids are----------- while those containing non-proteinaceous prosthetic group are------------------------

b) A Zn-containing enzyme, which is a conjugated protein is---------------

c) A class of enzymes involving the conversion of chemical energy into mechanical work fulfills a --

d) Proteins that act as structural elements are----------------------------------

e) -------------------------provide defence to the body against invading organisms and infections.

f) A protein consisting of more than one chain, or the shape in which those separate chains bond together is--------------------------------.

g) Meat muscle proteins can be categorized as------------------------------ .

h) Endosperm proteins act as ------------------------------ while bran proteins provides--------------------------- .

4.3 FUNCTIONAL PROPERTIES OF PROTEINS

It may be clear by now that functionality (as implied to food ingredients) refers to *'any property aside from the nutritional attributes that influence usefulness of ingredients in the food'*. Most of the functional properties affect the sensory characteristics (especially textural attributes) of foods, but also can play a major role in the physical behavior of food and food ingredients during their preparation.

Thus, *functional properties of proteins are those physico-chemical properties that enable the proteins to contribute to the desirable characteristics of the food*. You may recall reading about these physical, chemical properties of proteins in the Nutritional Biochemistry Course, in Unit 2. For your convenience, we have summarized the physical properties here.

So far, we have learnt that proteins may be added as components of foods for functional, nutritional or economic benefits. Potential functional benefits include *emulsification* and *stabilization*, increased *viscosity*, improved a*ppearanc*e, *taste* or *texture*, *form foams* and *gels* and *binding of fat* or water. These functional properties allow the technologist to modify flow properties, emulsify, form gels and foams or bind water and fat. Nutritional benefits include lowering the caloric contents of foods, increasing the protein level and balancing the amino acid profile. Of course, the economic or cost considerations are also important while using protein as an ingredient. An example of an economic benefit would be increased yield of the product from the use of a protein additive. It is also important to know that the type of protein (animal or plant origin) and the structure of protein will determine its functional properties. Three groups of functional properties of proteins have been identified. These include:

a) Hydration properties (dependent on protein-water interactions), which include properties like swelling, adhesion, dispersibility, solubility and viscosity.

b) Properties related to protein-protein interactions, which involves the processes of precipitation, gelation and formation of other structures (like protein doughs and fibers).

c) Surface properties, which relates primarily to surface tension, emulsification and foaming characteristics of proteins.

As you can see, these three groups are not totally independent. For example, gelation involves not only protein-protein interactions but also protein-water interactions. Also viscosity and solubility are both dependent on protein-water as well as protein-protein interactions. Let us learn about these functional properties, beginning with hydration properties.

a. Hydration Properties

General conformation of individual proteins in solution is largely dependent on the interaction with water. The progressive hydration of proteins starting from the dry state, the sequential steps are shown in the figure 4.2, are postulated:

Many functional properties of protein preparations are related to this progressive hydration. Water absorption (water uptake, affinity or binding), swelling, wettability, water holding capacity (water retention) and also cohesion and adhesion are related to the Ist four steps (figure 4.2), whereas dispersibility and viscosity (or thickening power) involves 5th step also. Final state of protein, either soluble or insoluble (partially or totally) is also related to important functional properties, such as solubility or instant solubility (in which all five steps take place rapidly). Gelation implies 'the formation of well-hydrated insoluble mass with specific protein-protein interactions'. Finally, surface properties, such as emulsification and foaming, necessitates a high degree of protein hydration and dispersion in addition to their characteristics.

Let us learn more about the hydration properties, which include solubility, viscosity etc.

Precipitation/Solubility of Proteins

Most of the functional properties are dependent on the degree to which the proteins are soluble. The solubility behaviour provides a good index of potential application of proteins. This is so because the degree of insolubility is probably the most practical measure of protein denaturation and aggregation and because proteins that initially exist in a denatured, partially aggregated state, often have an impaired ability to participate effectively in gelation, emulsification and foaming.

Note, in general, proteins, which are highly soluble, may be used in applications where emulsification, whipping and film formation are important whereas low solubility may be desired in applications with high protein levels and when limited emulsification or protein-protein interactions are needed.

Solubility of proteins is markedly and irreversibly reduced when heating is involved. However, heat treatments may be unavoidable to achieve other objectives (microbial inactivation, removal of off-flavor, removal of water and others).

Assumption that the proteins must have a high initial solubility as a prerequisite for other functional properties is not always correct. It has already been noted that water absorption of a protein ingredient sometimes can be improved by prior denaturation and partial insolubilization. This is in agreement with the fact that the formation of emulsions, foams and gels can involve various degrees of protein unfolding, aggregation and insolubilization.

On the other hand, whey proteins and some other proteins must have reasonably high initial solubility, if they are to function well in the emulsification, foams and gels. Soluble caseinates have better thickening and emulsifying properties than isoelectric casein (less soluble). Perhaps the main advantage of insolubility is that it permits rapid and extensive dispersion of protein molecules and particles which leads to a finely dispersed colloidal system with homogeneous macroscopic structure and smooth texture. Also, initial solubility facilitates protein diffusion to air/water and oil/water interface, thus improving their surface activity.

Viscosity, Gelation and Texturization

Viscosity reflects resistance to flow. The main single factor influencing the viscosity behavior of protein fluids is the apparent diameter of the dispersed molecule, which is dependent on the following parameters :

a. Intrinsic character of protein molecule (molar mass, size, volume, structure and asymmetry, electric charges and ease of deformation), environmental factors such

as pH, ionic strength and temperature, can modify these characteristics through unfolding;

b. Protein solvent interaction which influence swelling, solubility and hydrodynamic sphere surrounding the molecule, and

c. Protein-protein interactions which determine the aggregates. Protein ingredients are generally used at a high concentration at which protein-protein interactions predominate.

Viscosity and consistency of protein systems are the important functional properties in fluid foods, such as beverages, soups, sauces and creams. Correlation between viscosity and solubility is not simple. Insoluble heat denatured protein powders do not develop high viscosity when placed in aqueous medium. Highly soluble protein powders with low water absorption and swelling capacities (whey proteins) also exhibit low viscosity at neutral or IpH. Soluble protein powders with high initial water absorption capacities (sodium caseinates and some soy protein preparations) develop a high viscosity. Thus, for many proteins, a positive correlation is observed between water absorption and viscosity.

Gelation refers to the process where denatured molecules aggregate to form an ordered protein network. Proteins can form a well-ordered gel matrix by balancing protein-protein and protein-solvent interactions in food products. These gel matrices can hold other food ingredients in producing food products, like gelatin, yoghurt, comminuted meat products, tofu and bread doughs.

Gelation is an important functional property of several proteins that plays a major role in preparation of many foods, including various dairy products, coagulated egg whites, gelatin gels, various heated, comminuted meat or fish products, soy bean protein gels, vegetable proteins texturized by extrusion or spinning and bread doughs. Protein gelation is utilized not only for the formation of viscoelastic gels but also for improved water and fat absorption, thickening, particle binding (adhesion) and emulsion or foam stabilizing effect.

While studying about gelation, it is also important to differentiate it from other related phenomena in which the degree of dispersion of protein solution is decreased. For eg.

- ***Association:*** refers to changes occuring at subunit or molecular level.
- ***Polymerization or aggregation:*** involves formation of large complexes.
- ***Precipitation:*** includes all aggregation reactions with total loss of solubility.
- ***Flocculation:*** random aggregation reaction in the absence of denaturation; often occurs because of suppression of electrostatic repulsion between the chains.
- ***Coagulation:*** random aggregation with denaturation and aggregation reactions where protein-protein interactions predominate over protein-solvent interactions and forms a coarse coagulum.

Next, let's look at the texture function of proteins.

Texturization

Proteins constitute the basis of structures and texture in several foods, whether these come from living tissue (myofibrills in meat or fish) or from fabricated substances (bread dough and crumb, soy or gelatin gels, cheese, curds, sausage, meat emulsion etc).

Also, there are a number of texturization processes that begin with soluble vegetable or milk proteins and that lead to film or fiber like products with chewiness and good water holding capacity and that have the ability to retain these properties during subsequent hydration and heat treatment. These texturized proteins are often used as meat substitutes and/or extenders. Also, some texturization processes are done for the purpose of retexturization or reforming animal proteins such as beef or poultry meat. Known physicochemical basis of some of these texturization processes are presented below:

1. Thermal Coagulation and Film Formation: Concentrated soy proteins can be thermally coagulated on a flat metallic surface, such as that of a drum dryer. Resulting thin, hydrated films can be folded, pressed together and cut.

2. Fiber formation: Fiber spinning of vegetable (especially soy) and milk proteins bears many similarities to the spinning of synthetic textile fibers. It is usually necessary to start from isolates containing 90% protein or more. Four to five successive operations are necessary and can be done continuously.

3. Thermoplastic Extrusion: This is a major technique used for vegetable proteins at present. Thermoplastic extrusion leads to dry fibrous and porous granules or chunks, (rather than fibers) which upon rehydration, possess a chewy texture. Starting material need not to be protein isolates, thus less costly protein concentrates or flours (containing 45-70% protein) can be used. Casein or gluten can be added as such. Addition of small amount of starch or amylose improves the final texture, but a lipid content above 5-10% is detrimental. Addition of 3% sodium chloride or calcium chloride also firms the texture. Good texturization by this process requires proteins with appropriate initial solubility, high molecular weight and development of proper plasticizing and viscosity properties of protein-polysaccharide mixture within the dye.

After texturization, we move on to *properties related to protein-protein interactions.*

b. Properties related to protein-protein interactions

Properties related to protein-protein interactions include dough formation, one of the important functional properties of proteins. Let us get to know about dough formation.

Dough Formation

You already know that gluten is the protein found in wheat. A unique property of gluten proteins of wheat grain endosperm (and to a lesser extent of rye and barley grains) is their ability to form a strongly cohesive and viscoelastic mass or dough, when mixed and kneaded in presence of water at ambient temperature. In addition to glutens (gliadin and glutenins), wheat flour contains starch granules, pentosans, polar and non polar lipids and soluble proteins, all of which contribute to the formation of dough network and/or the final texture of bread.

Composition and large size of gliadins and glutenins explain much of the behaviour of gluten. Due to their low content of ionizable amino acids, the gluten proteins are poorly soluble in neutral aqueous solutions. Rich in glutamine (>33% by wt.) and in hydroxy amino acids, they are prone to hydrogen bonding which accounts largely for water absorbing capacity and for the cohesion and adhesion properties of gluten. Latter properties also derive in part from the presence of many apolar amino acids and the resulting hydrophobic interactions that contribute to protein aggregation and binding of lipids and glycoproteins. Finally, the ability of forming numerous -S-S- cross linkages accounts for the ease with which these proteins interlink tenaciously in dough.

We have been kneading doughs for long, without understanding the process going on within. What are the changes occurring in gluten proteins during dough formation? Box 4.3 presents a detailed discussion on this topic. You will find this information interesting.

Box 4.3 : Changes In Gluten Proteins During Dough Formation

Initially, gluten is formed when flour and water are mixed together. The proteins in the flour, glutenin and gliadin cross link, using water as a vehicle to form gluten. Enhancing this gluten structure is important relative to developing a gas retaining structure in the chapati/bread. When the hydrated bread flour is mixed and kneaded, the gluten proteins orient themselves aligns and partially unfolded. This enhances hydrophobic interaction and formation of disulphide bridges through -S-S- interchange reactions. A 3-dimensional viscoelastic protein network is established, as the initial gluten particles transform into this membrane (film), thus serving to entrap starch granules and other flour components. Cleavage of disulphide bridges by reducing agents such as cysteine, destroys the cohesive structure of hydrated gluten and bread dough ; the addition of agents such as bromates, increase toughness and elasticity. "Strong" flours from certain wheat varieties require long mixing time and give very cohesive dough. "Weak flours" are less effective and gluten network breaks down when the energy or duration of mixing exceeds a certain level, probably because of -S-S- bonds are ruptured (especially in absence of air). Dough strength appears to be related to a large content of high molecular weight glutenins including totally insoluble "residue proteins". From experiments with "reconstituted" wheat flours of varying gliadin and glutenin ratios, it can be postulated that the glutenins are responsible for the elasticity, cohesiveness and mixing tolerance of dough whereas gliadins facilitate fluidity, extensibility and expansion of the dough, thus contributing to a larger bread loaf volume. A proper balance of the proteins is essential for bread making. Excessive cohesion (glutenins) inhibit the expansion of trapped CO_2 bubbles during fermentation, the rise of the dough and the subsequent presence of open air cells in the bread crumb. Excessive extensibility (gliadins) results in gluten films that are weak and permeable; thus retention of CO_2 is poor and dough collapse may occur.

C. Surface properties of proteins

The surface properties relates primarily to surface tension, emulsification and foaming characteristics of proteins, which are discussed herewith:

Emulsifying properties of proteins

Proteins are the surface-active substances, which are extensively used in the food industry as emulsifiers to manufacture products such as desserts, spreads or whipped cream.

Protein Stabilized Food Emulsions: Many food products are emulsions (eg. milk cream, ice creams, cream, butter etc.) and protein constituents often play a major role in the stabilization of these colloidal systems. In the fresh milk, soluble proteins are immunoglobulins. Homogenization of milk increases emulsion stability because it reduces the size of fat globules and because newly formed casein submicelles displace the immunoglobulins and adsorb to fat globules.

The proteins stabilize emulsions and contribute physical and rheological properties, like thickness, viscosity, elasticity and rigidity that determine resistance to droplet coalescence. Ionization of amino acid side chains may also take place depending on the pH and this provides electrostatic repulsive force that favors emulsion stability. This functional property is important in the formation of many common food products, such as salad dressings and sausages.

Proteins are generally poor stabilizers of water/oil (w/o) emulsion. You will be reading about emulsions in details in unit 7 of this course. This may be attributable to the predominantly hydrophobic nature of most proteins, causing the bulk of an adsorbed protein molecule to reside on the water side of interface.

Proteins can bind to water, lipids, volatile flavours and other substances and possess important functional properties. Let's get to know them.

Foaming Properties, Binding of Flavour and Other Substances

To understand the foaming properties of proteins, we need to know some basic aspects of foam foods**.** ***Foam foods*** are ***u***sually colloidal dispersion of gas bubbles in a continuous liquid or semisolid phase that contains a soluble surfactant. (Surfactant is a chemical compound that acts as a surface modifier which reduces the surface tension of the liquid). A large variety of food foams produced with proteins, exist with widely differing textures, such as cakes, whipped creams and toppings, ice creams etc. In many cases, gas is air (occasionally CO_2) and the continuous phase is an aqueous or suspension containing proteins. You will read more about foams in unit 7.

Next, what are the properties basic to proteins, to be a good foaming agent? A protein must:

- be able to rapidly absorb at the air-water interface during whipping,
- undergo rapid arrangement and rearrangement at the interface, and
- form cohesive viscoelastic film.

Flavour Binding

Some protein preparations, although acceptable from a functional and nutritional stand point, necessitate a deodorizing step to remove the bound off-flavors. Various substances, such as aldehydes, ketones, alcohols and oxidized fatty acids may cause beany or rancid odours and bitter or astringent taste. When bound to proteins or to other constituents, these substances are released and become perceptible after cooking and/or mastication. Some are so strongly bound that even steam or solvent extraction do not remove them.

Quite different from the problem of off-flavour removal, it may be useful to use proteins as carriers for desirable flavours. It is of interest to impart a meat flavour to texturized vegetable proteins. Ideally, all of the volatile constituents of desirable flavour must remain bound during storage, possibly also due to processing and then be released quickly and totally in the mouth without distortion. Problems mentioned above can be solved through investigation of the mechanism by which volatile compounds bound to proteins. Let's find out.

Interactions between Volatile Substances and Proteins

Flavour binding may involve adsorption at the surface of food or penetration to the food interiority by diffusion (absorption). By adsorption we mean, a surface phenomenon that involves adhesion of the molecules of gases, dissolved substances, or liquids in more or less concentrated form to the surface of solids/liquids with which they are in contact.

Flavour binding by adsorption implies the mechanism of physical or chemical adsorption and hydrophobic interaction. Polar compounds, such as, alcohols are bound via hydrogen binding but hydrophobic interactions with nonpolar amino acids predominate in the binding of low molecular weight volatile compounds.

In some cases, volatile compounds bind to proteins via covalent linkages and the process is usually irreversible. Irreversible fixation is more likely to occur with the volatiles of high molecular weight.

Binding of Other Compounds

In addition to water, lipids and volatile flavours, food proteins can bind a number of other substances through weak interactions or through covalent bonds, depending upon their chemical structure. Eg. pigments, synthetic dyes (which may be used for analytical determination of proteins) and substances with mutagenic, sensitizing biological activity. Such binding may result both in enhanced toxicity or detoxification and in some cases; the nutritional values can be adversely affected.

Check Your Progress Exercise 2

1. Fill in the blanks:

a) In wheat proteins, gliadins are responsible for ----------------------whereas glutenin imparts ---------------------- to the dough.

b) The three groups of functional properties are-------------------------, ------------------, and --------------------.

c) -------------- is one of the factors affecting protein solubility.

d) Colloidal dispersion of gas bubbles in a continuous liquid or semisolid phase that contains a soluble surfactant are ------------------- foods.

e) Highly soluble proteins are used in three applications such as ----------------------, -------------------, and ----------------------------.

2. What do you understand by the term functional properties? List the three functional properties of proteins.

----

3. Following are the functional properties of proteins. Comment on the role of these in food preparation.

a) Gelation

----

b) Texturization

----

c) Stabilizer

Having learnt about the functional properties of proteins, we now focus on the application of proteins. You may have heard about protein concentrates, isolates etc. What are these products? The next section unfolds the discovery, uses of these products.

4.4 PROTEIN CONCENTRATES, ISOLATES AND HYDROLYSATES AND THEIR APPLICATIONS

The first question that may come to your mind is why do we need to concentrate or isolate a protein from a product? The major purpose of the preparation of concentrates and isolates from a protein source is to increase the concentration of proteins by the removal of non protein ingredients form the source, so that the smaller amounts can be used in the formulation to impart nutritional as well as functional properties.

The methods utilized for the removal of non-protein ingredients should be such that it should not affect the nutritional and functional properties of the protein to a great extent. Most of the work has been done on the preparation of soy protein isolates and concentrates and whey protein concentrates. Let's learn from these discoveries.

4.4.1 Protein Concentrates

In this section, we will learn about the soy protein and whey protein concentrates. What are they and what are their uses? Let's get to know them.

A. Soy Protein Concentrates

The Association of American Feed Control Officials, Inc. (AAFCO) specifies soy protein concentrates as follows:

"Soy Protein Concentrate is prepared from high quality, sound, clean, dehulled soybean seeds by removing most of the oil and water soluble non-protein constituents and must contain not less than 70% protein on a moisture free basis."

Edible soybean protein concentrates are relatively new products. Their availability as commercial products dates from 1959. In the last 30 years or so, these versatile products have become important ingredients, well accepted by many food industries. In many applications, they simply replace soy flours. In others, they have specific functions, which cannot be performed by soy flours.

Historically, the need for the development of soybean protein concentrates stemmed primarily from two considerations: to increase protein concentration and to improve flavour. The products containing about 70% protein are prepared from defatted meal by selective extraction of the soluble carbohydrates (sugars). Extraction with aqueous alcohol is the most common process, but other methods of production are also available. The concentrates are essentially bland.

Soybean protein concentrates normally cost 2 to 2.5 times more than defatted soy flour. Considering the relative protein contents of these two products, the cost per unit weight of protein is about 80% higher in the concentrate.

The starting material for the production of soy protein concentrates is dehulled, defatted soybean meal with high protein solubility (white flakes). The concentration of protein is increased by removing most of the soluble non-protein constituents. These constituents are primarily soluble carbohydrates (mono, di and oligosaccharides), but also some low molecular weight nitrogenous substances and minerals. Since some low molecular weight proteins are also extracted along with the sugars, the amino acid composition of the concentrates may differ slightly from that of the original flour.

Now let us look at the uses of this product.

Utilization of Soy Protein Concentrate

Soy protein concentrates are used in food products for their nutritional characteristics or for their functional properties or for both. Nutritionally, the attractive features of concentrates include their high protein content, the near-absence of anti-tryptic and other anti-nutritional factors, the absence of flatulence and the substantial "dietary fibre" content. The nutritional value of the protein in the concentrates of different types, expressed as Protein Efficiency Ratio (PER), is slightly lower than that of soy flour protein. This is probably due to the slight fractionation effect of the extraction process, mentioned above. The most important functional characteristics of soy protein concentrates are water-binding (water adsorption) capacity, fat binding capacity and emulsification properties. The use of soy protein concentrates in different applications in food industry is highlighted herewith.

a. Bakery products

Unlesss higher protein fortification levels are necessary, there is no special reason for using soy protein concentrates in bakery products. Nutritionally and functionally, soy flours do the same job, more economically.

b. Meat products

This area probably represents the most important application of soy protein concentrates (SPC) in the food industry. SPC is used mostly in comminuted meat, poultry and fish products (patties, emulsion type sausages, fish sticks etc.) to increase water and fat retention. The nutritional contribution of soy protein in low-meat, high-fat, low-cost products may also be significant. Typical usage levels, on moisture-free basis, are 5-10% in patties, 2-8% in chilli, 2-12% in meatballs, 3.5% maximum in sausages and 5-10% in fish sticks.

c. Other uses

Soybean protein concentrates have been used as stabilized dispersions in milk-like beverages and simulated dairy products, such as sour cream analog.

After soy protein concentrates we shall study about the whey protein concentrates.

B. Whey Protein Concentrates

You already know that whey is the residual liquid substance that is obtained by separating the coagulum from milk during cheesemaking. There are important components contained in whey, the most valued of which are the proteins which are highly regarded for their nutritional properties. The major whey proteins are α-lactalbumin and β-lactoglobulin. These globular proteins offer the most diverse functional benefits and have the greatest potential when used in further processed foods.

What, then, is the whey protein concentrate?

Whey protein concentrates (WPC) are the products derived from whey from which the water, minerals and lactose have been removed. WPC is a white to light cream-colored product with a bland, clean flavor. It is manufactured by drying the material resulting from the removal of sufficient non-protein constituents from pasteurized whey so that the finished dry product contains 25% or more protein. The non-protein constituents are removed by physical separation techniques such as precipitation, filtration, or dialysis. WPC can be used in fluid, concentrate, or dry product form. Safe and suitable pH-adjusting ingredients may be used to adjust the acidity of WPC.

Whey protein concentrate (WPC) is a highly nutritious ingredient manufactured from fresh dairy whey and it is spray dried to provide an excellent source of low fat dairy protein. Useful properties, such as high solubility and water retention capacity, make it an ingredient of choice in a wide variety of functional and processed foods, beverages and health supplements. Whey protein concentrates can also contribute a high level of viscosity and structure to food formulations as well as a smooth texture. Generally, WPC with higher protein content have improved functionality over those with lower protein content. Some of the basic functionalities of WPC are highlighted in Box 4.4.

Box 4.4 Functional Properties of WPC

Functional property	Mode of action	Food system
WaterBinding/ Hydration	Proteins can help reduce formula costs as the proteins hold additional water.	Meats, beverages, breads, cakes, sausages
Gelation/Viscosity	Protein-protein interactions produce matrix formations and setting	Salad dressings, soups, setting cheeses, baked goods, gravies, meats
Emulsification	Proteins stabilize fat emulsions	Sausages, soups, cakes, salad dressings, infant foods
Foaming/Whipping	Proteins form stable film. Foaming properties are best when the whey proteins are undenatured, not competing with other surfactants at the air/water interface.	Whipped toppings, chiffon cakes, desserts
Browning/Flavour/ Aroma	Proteins contribute to browning by reacting with lactose and other reducing sugars present in a formulation, providing colour to heated products. WPC is bland tasting and contribute no foreign or off-flavours when used as an ingredient.	Confections, meats in microwave, sauces, breads, low-fat baked goods, soups, dairy products.

What are the uses of WPC?

Whey protein concentrates are used extensively in the manufacture of baked goods, where they increase the effectiveness of shortening through better dispersion and contribute to product browning, crust and flavor development. High viscosity whey protein concentrates are ideally suited to use in ice cream, processed cheese, sauces/slices and various fresh dairy and specialized nutritional applications. Whey proteins have also been designed with enhanced heat stability, water retention and gelation for superior performance in beverages, infant formula, soups, sauces, frozen yogurt and ice cream.

WPC of 35 percent protein is commonly used as a replacement for skimmed milk, as well as a stabilizer and fat mimetic in yogurt, bakery mixes, dietetic foods, infant foods and confections. Its water-binding properties, fat-like mouth-feel and gelation properties are of particular benefit when used in these further processed products.

WPC of 50, 65 or 80 percent protein are especially suited for use in nutritional drinks, soups, bakery products, meat, dietetic foods, low-fat products and protein-fortified beverages. They are especially noted for their ability to completely dissolve in a wide range of pH conditions.

Defatted WPC powder containing 80 - 85 percent protein is an excellent alternate ingredient to use in certain applications, more notably as an economical egg-white replacer in whipped products such as meringues, modern ice-cream and toppings.

So far we have studied about the soy and whey protein concentrates. It is interesting to note that soy and whey protein also exist as isolates. What is the difference between concentrates and isolates? Read to find out.

4.4.2 Protein Isolates

Before we begin our discussion on protein isolates, let us first get to know how protein concentrates differ from isolates. Basically, the two differ in the process by which the proteins are produced, and the quality of the protein. Isolate is always higher quality protein. Do remember.

In this section, we will focus on soy protein isolates.

Soybean protein isolates:

Soy protein isolates are the most pure and refined soy protein available. Isolated soybean proteins (ISP), or soybean protein isolates, are the most concentrated form of commercially available soybean protein products. They contain over 90%

protein, on a moisture free basis. Soy protein isolates have been known and produced for industrial purposes, mainly as adhesives for the paper coating industry, well before World War II. ISP's for food use, however, have been developed only in the early fifties.

The specification of the Association of American Feed Control Officials, Inc. (AAFCO) defines ISP as "*Major proteinaceous fraction of soybeans prepared from dehulled soybeans by removing the majority of non-protein components and must contain not less than 90% protein on a moisture-free basis.*"

The basic principles of ISP production are simple. Soybean protein isolates are obtained by selective solubilization of the protein (e.g. alkaline extraction), followed by purification of the extract and precipitation of the protein (e.g. by acidification to the isoelectric point). Isoelectric isolates are insoluble in water and have practically no functional features. They can be converted to sodium, potassium or calcium proteinates by dissolving isoelectric proteins in the appropriate base and spray-drying the solution. Sodium and potassium proteinates are water-soluble. They are used mainly for their functional properties, such as emulsification or foaming. One of the by-products of the protein isolation process, the insoluble residue, is also commercialized for its remarkable water absorption capacity and as a source of dietary fibre.

Since spray-drying is the common drying method in the production of ISP, the primary physical form of ISP in commerce, is that of fine powders. Structured forms, such as granules, spun fibres and other fibrous forms are made by further processing.

Being almost a pure protein, ISP can be made to be practically free of objectionable odour, flavour, colour, anti-nutritional factors and flatulence. Furthermore, the high protein concentration provides maximum formulation flexibility when ISPs are incorporated into food products. These and other advantages have been the source of highly optimistic forecasts regarding the widespread use of ISP. The various uses of ISP in food applications are discussed herewith.

Uses of Soy protein isolates

The applications of ISP in various food products are enumerated herewith:

- *Meat products*

The major application of ISP in connection with meat and related products is based on the use of texturized ISP, in one form or another, to replace meat.

In emulsion type sausages, such as frankfurters and bologna, ISP and proteinates are used for their moisture and fat binding properties and as emulsion stabilizers. The use of ISP in these products permits reducing the proportion of expensive meat in the formulation, without reducing the protein content or sacrificing eating quality. Methods for incorporating soy protein products into whole muscle meat have been developed recently.

- *Seafood products*

The most important application in this category is the use of ISP in fish sausage and surimi based restructured fish products in Japan. Surimi is an extensively washed, minced fish flesh.

- *Cereal products*

ISP is sometimes used instead of, or in combination with isolates and soy flour, in the formulation of milk replacer mixtures in bakery products. ISP has been used for protein fortification of pasta and specialty bread. In these applications, the high protein content and blandness of ISP are clear advantages.

- *Dairy-type products*

Soybean protein isolates are used in non-dairy coffee whiteners, liquid whipped toppings, emulsified sour cream or cheese dressings, non-dairy frozen deserts etc. The basis for these applications is, demand for non-dairy (all-vegetarian, cholesterol-free, allergen-free) food products, as well as economy. Imitation cheeses have been produced from isolated soy proteins, with or without milk whey components. The types of cheeses which can be produced include soft, semi-soft, surface-cultured (imitation Camembert) and ripened hard cheeses.

- *Infant formulas*

Infant formulas, where milk solids have been replaced by soy products, are well established commercial products. ISP is the preferred soy ingredient, because of its blandness, absence of flatus-producing sugars and negligible fibre content.The principal market for these products are lactose-intolerant babies. However, soy protein based dietetic formulas are finding increasing use in geriatric and post-operative feeding as well as in weight reduction programs.

- *Other uses*

Partially hydrolysed soy proteins possess good foam stabilization properties and can be used as whipping agents in combination with egg albumen or whole eggs in confectionary products and desserts.

Isolated soybean protein has been shown to be an effective spray-drying aid in fruit purees. In this application, it can replace maltodextrins, with the advantage of contributing protein to the final product. A nutritious "shake" base was produced by spray-drying ripe banana puree containing up to 20% ISP on dry matter basis.

Before we end, a final word on protein isolates. The cost of isolated soybean proteins is five to seven times higher than that of defatted soy flour. On an equal protein weight basis, the cost ratio of these two products is nearly 3:1. The main reasons for the added cost will become evident from the description of the manufacturing methods for ISP.

Now, we move on to the third concept, i.e. protein hydrolysates.

4.4.3 Protein Hydrolysates

What are protein hydrolysates? *Proteins that have been treated with enzymes to break them down into amino acids or shorter peptides are referred to as protein hydrolysates.*

Protein hydrolysates are valued for their superior nutritional qualities, including increased bioavailability and reduced antigenecity. Several enzymatic modifications of proteins / enzymes are known to occur in biological systems. Such modifications of proteins *in vitro* can be used to improve their functional properties. Only few of the enzymatic modifications of proteins are practical for modifying proteins for food use.

Hydrolysis of food proteins using proteases (trypsin, chymootrypsin, papain and thermolysin) alters their functional properties. Extensive hydrolysis by nonspecific proteases, such as papain, cause stabilization of even poorly soluble proteins. Such hydrolysates usually contain low molecular weight epties of the order 2-4 amino acids residues. Extensive hydrolysis damages several functional properties, such as gelation, foaming and emulsifying properties. These modified proteins are useful in liquid-type foods, such as soups and sauces, where solubility is a primary criterion and feeding a person who might not be able to digest solid foods. Partial hydrolysis of proteins either by using site-specific enzymes (such as trypsin or chymotrypsin) or by control of hydrolysis time, often improves foaming and emulsification properties, but not gelling properties. With some proteins, partial hydrolysis may cause a transient decrease in solubility, because of exposure of the buried hydrophobic regions.

The drawback of many protein hydrolysates, is that when hydrolysed, most of the food proteins liberate bitter tasting peptides, which affect their acceptability in certain applications. The bitterness is associated with their mean hydrophobicity. The intensity of bitterness depends on the amino acid composition and sequence and the type of protease used. Hydrolysates of hydrophilic proteins, such as gelatin; are less bitter than the hydrolysates of hydrophobic proteins, such as casein and soya proteins. Protease that show specificity for cleavage at hydrophobic residues, produce hydrolysates that are less bitter than those enzymes which have a broader specificity. Thus, thermolysin, which specifically attacks the amino side of hydrophobic residues, produces hydrolysates that are less bitter than those produced by low specificity trypsin, pepsin and chymotrypsin.

With this, we finish our study on proteins.

Check Your Progress Exercise 3

1. Fill in the blanks:

a) Protein concentrate or isolate have an ----------------- concentration of proteins by selective removal of the non protein matter from the source.

b) The nutritional value of protein concentrates is expressed as --------------------- .

c) One of the most important functional characteristics of SPC is ---------------------.

d) The two nutritionally valued proteins that form a part of whey are ------------------ and ----------------.

e) The main drawback of hydrolysates is that it liberates bitter tasting -----------------.

2. What are the nutritionally attractive features of SPC?

----

3. Mention any two applications of:

a) Whey Protein Concentrates

----

b) Soy Protein Isolates

----

4. What characteristics make ISP a preferred soy product?

----

5. How is an isolate different from a concentrate?

4.5 LET US SUM UP

Proteins, one of the major nutrients, are an essential component of our body tissues. Amino acids, the principal building blocks of protein, are twenty in number and vary in their composition, structure and properties. In this unit, we learnt about different types of proteins, i.e., sources of different types of proteins and functional properties. The important functional properties included viscosity and gelation. Viscosity refers to resistance to flow and is specifically crucial in preparation of fluid foods. Gelation refers to the process where denatured molecules aggregate to form an ordered protein network.

Finally, the unit focused on various protein concentrates, isolates, hydrolysates and their wide applications in food industry.

4.6 GLOSSARY

Adsorption : A surface phenomenon that involves adhesion of the molecules of gases, dissolved substances, or liquids in more or less concentrated form to the surface of solids/liquids with which they are in contact.

Amino acids : Monomeric units of proteins, having both amino and carboxylic groups in their structure.

Gelation : Formation of an ordered protein network when denatured molecules aggregate.

groups. In proteins these are the major determinant of the secondary structure.

Hydrogen Bonding : Non-covalent interaction between two opposite charged

Hydrolysate : Breakdown of proteins progressively to yield peptides or finally amino acids by the action of enzymes or chemical agents.

Hydrophobic Interaction : Major determinant of tertiary structure of proteins

Proteins : Complex nitrogenous compounds which consist of amino acids linked together by peptide bonds. They are the basic constituents of all living things and are a necessary part of the part of the food of all animals.

Single cell Protein : Proteins from sources, like algae, fungi, bacteria and yeast

Viscosity : Resistance to flow.

4.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Proteins can be classified based on:
   - Shape and size: fibrous or globular proteins.
   - Functional properties: Immuno, contractile, respiratory, structural, enzymatic, hormonal and carrier proteins.
   - Solubility and physical properties: Simple, conjugated and derived proteins.

2. The important functions of proteins in biological systems are as follows: (any two):
   - enzymes
   - membrane carriers
   - antibodies
   - structural element
   - hormonal messenger

3. Protein food sources can be divided into the following three categories:
   - Proteins of plant origin example meat, milk, eggs, fish etc.
   - Proteins of plant origin such as vegetable proteins, cereal proteins, seed proteins and nuts.
   - Single Cell Proteins.

4. The proteins obtained from microbial sources, i.e. algae, fungi, bacteria, yeast etc. are referred to as Single Cell Proteins. These are isolated from microorganisms. Some of the advantages of selecting microorganisms as a source of protein are:
   - High yield of proteins on dry weight basis.
   - Cost effective nutritional requirement.
   - Less area is required for the installation of plant for the production of proteins.
   - The plant may be designed in such a way that the processing can be done on a continuous basis instead of batch to batch basis.

5.

a) Homoproteins; Heteroproteins

b) alcohol dehydrogenase

c) mechanochemical role

d) keratins, collagens, elastins

e) immunoglobulins

d) Quaternary structure

e) Sarcoplasmic, contractile, stroma; sarcoplasmic, myofibrallar, connective tissue.

f) Structural component, food reserve; structure and protection to kernel.

1. Primary, Secondary, Tertiary and Quaternary are the different levels in which the protein structure is divided into.

2. The advantages of selecting micro-organisms as a source of protein are: high yield of proteins on dry weight basis; nutritional requirement is quite cheap; less area is required for the installation of plant for the production of proteins; and processing can be done on a continuous basis.

3. The major drawback of using algae as the source of protein is that it has a cellulosic cell wall, which is not digestible by human beings, thus causes nausea, vomiting, abdominal pain etc.

4.

Check Your Progress Exercise 2

1.

a) facilitating fluidity, extensibility and expansion; elasticity, cohesiveness and mixing tolerance.

b) hydration, surface, protein-protein interactions

c) pH, ionic strength, solvent and temperature

d) foam foods

e) emulsification, whipping and film formation.

2. Those physico-chemical properties that enables the protein to contribute to the desirable properties/ characteristics of food are termed as functional properties. A few functional properties of proteins are:

- Hydration properties that includes solubility, viscosity, gelation and texturization
- Protein-protein interactions which include dough formation
- surface properties which include emulsifying properties etc.

3.

a) Gelation refers to the process where the denatured molecules aggregate to form an ordered protein network by balancing protein-protein and protein-solvent interactions in the food products. These gel matrices can hold other food ingredients in processing food products, such as, dairy products, meat or fish products, vegetable proteins texturized by extrusion or spinning and bread dough.

b) Texturization process lead to film or fiber-like products with chewiness and good water holding capacity along with an ability to retain these during hydration and heat treatment. Texturized products are often used as meat substitutes and/or substitutes.

c) In foams, proteins form a protective layer (film) by adhering at the gas liquid interface and thus prevent the foam to collapse, thus act as a stabilizer.

Check Your Progress Exercise 3

1.

a) increased

b) Protein Efficiency Ratio

c) Water-binding capacity, fat-binding capacity and emulsification properties

d) α-lactalbumin and β-lactoglobulin

e) peptides

2. The nutritionally attractive features of SPC are high protein content, the near absence of anti-tryptic and anti-nutritional factors, absence of flatulence and substantial dietary fibre content.

3.

a) The applications of Whey Protein Concentrates are as a health supplement; bakery products; ice creams; processed cheese.

b) The applications of Soy Protein Isolates are in the following products meat; seafood; cereal; dairy-type products and infant formulas.

4. The characteristics which make ISP a preferred product are: blandness, absence of flatus-producing sugars and negligible fibre content.

5. An isolate contains not less than 90% protein on a moisture-free basis while concentrate contains not less than70% protein on a moisture-free basis.

UNIT 5: VITAMINS AND MINERALS

Structure

5.1 INTRODUCTION

In this unit we will study about vitamins and minerals. You may have already studied the structure and physico-chemical properties of vitamins and minerals in the course on Food Biochemistry. The course Advance Nutrition also gives you the information on vitamins and minerals. We suggest, like in the other units you have studied so far, please organize the study of this unit along with the respective units on vitamins and minerals in the other two courses. This will give you a comprehensive understanding of the different aspects of vitamins and minerals.

Here in this unit our focus is on application of vitamins, minerals in the food and/or pharmaceutical industry. In this context, you will find a brief description about each of the vitamin and mineral, in terms of its characteristics, occurrence, importance and determination. This information will assist in your understanding of these vital substances.

Objectives:

After studying this unit you will be able to:

- highlight the importance of vitamins and minerals,
- discuss the occurrence and determination/estimate of vitamins/ minerals in food or in test sample, and
- describe the functional role of vitamins and minerals, particularly in the food industry.

5.2 VITAMINS

Vitamins, as you may already know, derive its name from the word 'Vital Amine'. These are the organic compounds required for normal metabolism, growth and development, and regulation of the cell functions. Vitamins classified as water soluble or fat soluble as highlighted in Figure 5.1. In this section, we will learn about the characteristics, importance and application of vitamins, both water soluble and fat soluble. We begin with Vitamin A.

Figure 5.1 Classifications of Vitamins

5.2.1 Vitamin A (Retinol)

Purified vitamin A is a viscous yellowish oil. It is freely soluble in most organic solvents such as methanol, ether, acetone, chloroform and petroleum ether as well as in fatty oils like olive, sesame and groundnut. However, Vitamin A is insoluble in water. It is highly susceptible to the action of atmospheric oxygen and oxygen carriers, further to oxidizing agents and metal ions. Vitamin A is also rapidly destroyed by UV light. Even in diffuse day light, the vitamin A content of solutions is markedly reduced within a few hours. You must remember that vitamin A should be stored in a cool place, protected from light under vacuum or inert gas in air-tight containers or sealed ampules. You must understand that vitamin A itself is very unstable against external influences. For its use in foods and as therapeutics, therefore, only those derivatives with improved stability are used. Thus, esterification of the alcoholic group of vitamin A with acetic or palmitic acid produces compounds which are somewhat more stable. Vitamin A, therefore, is practically sold and used only in the form of concentrates and oily solutions of the acetate and palmitate and their formulations.

The importance of vitamin A is undisputable. You may already be aware about the functions/role of vitamin A in our body. Vitamin A is absolutely necessary for normal vision, both black and white and colour. Vitamin A deficiency in childhood leads to blindness. Vitamin A is highly important for the normal condition and functional maintenance of epithelial tissues. Vitamin A deficiency symptoms are manifest in characteristic changes of skin and mucosae. With prolonged vitamin A deficiency, cornification of the mucous membranes of the respiratory tract, the digestive tract and the urogential organs develops. Site of action of vitamin A is probably the protein metabolism of the epithelial cells. An early symptom of vitamin A deficiency is night blindness. The interrelationship between vitamin A and the individual hormones is also important. The sex organs show a high vitamin A content and ceases to function in vitamin A deficiency. Vitamin A and thyroxine levels are interrelated. Normally, vitamin A in the presence of fats and bile is absorbed mainly from the intestine and stored in the liver.

In addition, you will find information on how to determine / estimate vitamins / minerals in foods or in any test sample. As a food scientist, you will find this information very useful. The effort of processing on mineral content of food is another aspect covered in this unit. As advised for other units here too we will recommend that you look up the units on vitamins and minerals in the courses Nutritional Biochemistry and Applied Nutrition. Now let us learn about the occurrence of Vitamin A.

Occurrence

In the vegetable kingdom, vitamin A probably occurs in the form of its provitamins which belong to the group of carotenes. Carrots, spinach, lettuce, celery leaves,mangoes, papaya and dried apricots are especially rich in carotenes and carotene isomers. In the human beings and animals, you should know, the provitamins (carotenes) are converted into vitamin A in the intestinal mucosa. The most important provitamin is β-carotene. Other important sources of preformed vitamin A are the fish-liver oils (like codfish, Salmon, tunny fish and whale), butter, milk, egg yolk and animal liver.

Determination

Vitamin A assay is carried out by chemical method. This method is called Carr Price Reaction.

Vitamin A and the carotenoids produce an intense blue colour upon addition of a saturated solution of antimony trichloride in anhydrous and alcohol-free chloroform. This reaction is called Carr Price Reaction and used to determine Vitamin A. The absorption maxima is around 620 nm.

In another method, absorption of vitamin A dissolved in isopropyl alcohol is determined at wavelengths of 310, 325 and 334 nm. This method is suitable for the determination of pure vitamin A (or of the ester after their saponification), such as oily solutions as well as in tablets, coated tablets, capsules and other formulations.

Applications

- *Vitamin A dry powder*

Vitamin A dry powder is used in the (manufacture of dry mixtures) for which the oily ester concentrates are unsuitable or undesirable. Mainly, they are incorporated in dry formulations such as (coated tablets and capsules). Even in animal feed industry, vitamin A dry powder is preferred. The stability of vitamin A in the dry powder is increased by matrix coating of the esters with gelatin, thus protecting them from direct oxidation.

- *Water soluble Vitamin A*

Water soluble vitamin A is a yellowish green, slightly turbid, fluorescent liquid of faint characteristic odour. The taste is at first faintly sweet and then bitter. Water soluble vitamin A is especially suitable for the manufacture of solutions for oral administration. This preparation contains the palmitate of vitamin A. This ester which otherwise is only fat soluble, has been rendered miscible with water and aqueous liquids by a solubilizer. The stabilizer added to the preparation moreover delays possible loss of activity due to atmospheric oxidation.

5.2.2 Vitamin B Complex

The vitamin B complex comprises the vitamins B_1, B_2, B_6 and B_{12} as well as the vitamin B factors biotin, folic acid, nicotinic acid and its amide as well as pantothenic acid. Besides, inositol, choline and adenine (vitamin B_4) are considered as vitamins of the B complex. In nature, the active principles of the vitamin B complex mostly occur together.

In the human and animal metabolism, they form a functional unit, since, as components of the various coenzymes, they are essential members of reaction chains. They play a part in numerous metabolic processes such as cellular respiration, and energy production, carbohydrate conversion and the synthesis and breakdown of fats and amino acids. Because of their role in energetic metabolic processes, the vitamins are essential for the maintenance of vital processes. Because of this close interdependence and the multiplicity of functions, it is readily understood that the absence of one B complex factor will impair the efficacy of the other vitamins. Therefore, the symptoms associated with vitamin B complex deficiency may be manifold. They mainly affect growth, skin and mucous membranes, blood and nervous system. We will discuss the characteristics, importance and application of each of the B-complex vitamins one by one in this section.

5.2.2.1 Vitamin B_1 (Thiamine hydrochloride)

Thiamine hydrochloride is a white, crystalline powder, slightly hygroscopic, of an odour resembling yeast and of bitter to taste. It is freely soluble in water. Thiamine hydrochloride is soluble in glycerin, sparingly soluble in methanol and ethanol (95%), almost insoluble in absolute alcohol, acetone, ether, chloroform, benzene, fats and fatty oils.

Occurrence

Vitamin B_1 occurs widely in the vegetable kingdom. The richest sources for vitamin B_1, as you may already know, are yeast, grain germs and rice polish. Whole grain bread and potatoes are vitamin B_1 sources of considerable dietary importance. Animal tissues rich in vitamin B_1 are liver, kidney, brain and heart. Aqueous solutions of thiamine hydrochloride are unstable in the presence of alkalis and substances with alkaline reactions, atmospheric oxygen, metal ions and UV light. Moreover, the solutions are affected by reducing and oxidizing agents, especially in the neutral and alkaline ranges.

Determination

Vitamin B_1 is determined by chemical method and microbiological assay. In the chemical method, vitamin B_1 is oxidized in alkaline solution by potassium ferricyanide solution to form thiochrome. The latter may be extracted with isobutanol and the resulting vivid blue fluorescence measured.

In the microbiological assay, turbidimetric growth measurement of the specific culture of *Lactobacillus fermenti* ATCC 9338 and/or *Saccharomyces cerevisiae* ATCC 7753 is performed by titration against 0.1 N NaOH.

Applications

The steadily increasing consumption of white flours (insufficiently ground and thus low in vitamin content) by large sections of the population involves the risk of vitamin B_1 deficiency. By fortification of white flours with chemically pure vitamins of the B group, the population may retain its most important source of vitamin B.

Due to the manifold functions performed by vitamin B_1 in the metabolism, inadequate supply is manifest by a number of deficiency symptoms. Vitamin B_1 hydrochloride is used for the preparation of drug formulations of all types, especially of oral drop solutions, drops, tablets and others and also for the vitamin fortification of foods.

5.2.2.2 Vitamin B_2 (Riboflavin)

Riboflavin is a yellow to orange-yellow, crystalline powder of faint odour and intensely bitter taste. Its solubility in water is very slight and depends on the crystalline structure. The saturated aqueous solution of riboflavin shows neutral reactions to litmus (pH about 6.0). Solubility is markedly increased in the presence of various substances, especially sodium chloride, urea and nicotinamide. Riboflavin is also soluble in alkali hydroxide solutions, but will decompose. In the common organic solvents riboflavin is practically insoluble.

Aqueous solution shows a pronounced green-yellow fluorescence, which is maximal at a pH of about, 6-7 and disappears upon the addition of acids and alkalis. Riboflavin shows amphoteric reaction. The isoelectric point of riboflavin is around 6.0. The melting point is approximately 280-285°C. Riboflavin is inactivated by exposure to day light and UV light. Irradiation of an alkaline solution produces yellowish-green lumiflavin. In neutral or acidic solutions, the colourless lumichrome is formed along with varying amounts of lumiflavin.

In the presence of alkalis and materials giving alkaline reaction, aqueous riboflavin solutions are unstable. Also in the presence of strong reducing agents, metal ions and upon exposure to day light and UV light, the solution is not stable.

Importance

As a prosthetic group of the flavin enzymes, vitamin B_2 is involved in the reactions of almost all nutrients of plants and animals. They are designed to regulate redox processes. Riboflavin, thus, catalyzes the reactions of carbohydrates, fats, proteins and nucleic acids.

Occurrence

Vitamin B_2 (riboflavin) occurs in nature almost exclusively in a combined form i.e. esterified with phosphoric acid as riboflavin-5'-phosphoric acid ester. Vitamin B_2 occurs in a combined form in any plant and animal cell - yeasts, wheat, white bread, rye bread, fruits, nuts, spinach, cabbage, milk, cheese, egg yolk, fish, meat, rice bran, potatoes and others.

Determination

In the chemical method, the yellow-green fluorescence of aqueous solution of riboflavin is measured. In the microbiological assay, turbidimetric growth measurement or determination of lactic acid formed by *Lactobacillus casei* ATCC 7469 is performed.

Applications

Vitamin B_2 is used as a colour and nutrient in various food commodities such as baked foods, noodles and macaroni products, ice creams and soup mixes.

5.2.2.3 Vitamin B_6 (Pyridoxine hydrochloride)

Pyridoxine hydrochloride is a white, crystalline powder, practically odourless. The dry substance is sufficiently stable in air. With prolonged exposure to day light and UV light, it will change gradually. Pyridoxine hydrochloride is easily soluble in water. A 10% (w/v) aqueous solution shows a pH of about 3.0. Pyridoxine hydrochloride is moreover soluble in 95% ethanol. It is slightly soluble in acetone and practically insoluble in ether. The melting point is 206-212°C. Aqueous solutions of pyridoxine hydrochloride are incompatible in particular with oxidants, metal ions as well as day light and UV light.

Importance

In the human and animal organisms, vitamin B_6 acts in the form of pyridoxal. In the form of 5'-orthophosphate (Pyridoxal-5'-phosphate), pyridoxal is the prosthetic group of numerous enzymes of essential importance in the protein metabolism.

Occurrence

Vitamin B_6 activity is attributed to the 3 compounds–pyridoxol (pyridoxine), pyridoxal and pyridoxamine, generally comprised in the vitamin B_6 group. They occur in any living cell. While the quantitative share of pyridoxal is proportionately largest in the vegetable kingdom, the phosphates of pyridoxal and pyridoxamine predominate in the animal cell and in yeasts, vitamin B_6 is found abundantly in green plants, molasses, brewer's yeast, egg yolk and several animal organs such as liver and kidneys.

Determination

Colorimetric determination of indophenol dye using 2,6-dichloroquinone chloraimide as colour reagent or diethyl-p-phenylenediamine in the presence of an oxidizing agent. Microbiological determination is preferably made by turbidimetric measurement of the growth of *Saccharomyces carlsbergensis* ATCC 9080.

Applications

The heating processes employed in the industry for the sterilization of milk based formulations will greatly reduce their vitamin B_6 content. Possibly, as yet, unknown decomposition products of vitamin B_6 are formed/it is inactivated in these products during manufacture and storage, with the loss of vitamin activity.

An interesting fact of practical importance is the observation that the vitamin B_6 hydrochloride added to milk or milk preparation is more resistant to thermal sterilization than the vitamin B_6 naturally present in the milk. Loss of vitamin B_6 loss due to thermal sterilization of milk based preparation may thus be compensated by external addition of vitamin B_6 hydrochloride.

Check Your Progress Exercise 1

1. Fill in the blanks:

(i) Vitamin A is susceptible to the action of ---

(ii) Vitamin A destruction can be prevented by--

(iii) Vitamin A is used and sold as--

(iv) Richest sources of Vitamin B, are --

(v) The most convenient way to prevent the risk of vitamin B, deficiency is --

(vi) Riboflavin is unstable in the presence of---

(vii) Vitamin B_6 group comprises of --

2. Complete the following table by listing the application of the vitamins in food industry.

Sr.No.	Vitamins	Applications in food industry
1.	Vitamin A dry form	
2.	Vitamin A water-soluble	
3.	B_1	
4.	B_2	

5.2.2.4 Vitamin B_{12} (Cyanocobalamin)

Vitamin B_{12} refers to a group of Cobalt-containing corrinoids known as cobalamins. It is also called antipernicious- anemia factor, extrinsic factor. In human and animals, derivatives like hydroxycobalamin, adenosyl cobalamin and methyl cobalamin are the major compounds which are metabolically active. The latter two are the active co-enzymic forms. Cyanocobalamin is a synthetic form of Vitamin B_{12} that is widely used clinically due to its availability and stability which is transformed into active form in the body.

Importance

Vitamin B_{12} deficiency is manifest by the symptoms of pernicious anaemia (Addison-Biermer’s disease). An irreversible atrophy of the gastric mucose is primarily responsible for pernicious anaemia, causing loss of the intrinsic factor, which is predominantly produced in stomach. Vitamin B_{12} from the ingested food is bound by intrinsic factor that reaches intestine for absorption. In addition, vitamin B_{12} acts as a mediator in the formation of labile methyl groups for the synthesis of methionine. This explains its lipotropic and protein saving effect. In various animal species, increased growth may be produced by administration of vitamin B_{12}. Also, in children, the growth promoting activity of vitamin B_{12} has been observed.

Occurrence

Vitamin B_{12} is one of the cobalamin, a group of active principles widely occurring in nature. Vitamin B_{12} is present especially in liver, kidney, heart, brain, spleen, thymus and muscles. Larger amounts may also be detected in the intestine. In addition, considerable amounts are found in the culture media of various *Streptomyces* species and also in residue of streptomycin manufacture. Foods of plant origin are essentially devoid of Vitamin B_{12}.

Cyanocobalamin occurs as dark red crystals or as a crystalline hygroscopic powder of the same colour without odour and taste. Upon standing in the air, the anhydrous substance absorbs up to 12% water. Cyanocobalamin is soluble in water and 95% ethanol, but almost insoluble in ether, chloroform and petroleum ether. In the presence of alkalis and reactive alkaline compounds, reducing and oxidizing agents, aqueous solutions of cyanocobalamin are not stable. Cyanocobalamin substance and solution gradually decompose with discolouration by the action of day light and UV light. The activity of cyanocobalamin solutions may also be considerably affected by microbial growth. Cyanocobalamin should be kept in air tight containers protected against light and moisture in a cool place. To be protected against mold growth during storage.

Determination

Spectrophotometric determination of the characteristic ultraviolet absorption is suitable for the determination of pure vitamin B_{12} or of pure aqueous solution in the absence of interfering impurities. Microbiological assay is performed by any of the following:

- Determination of the diffusion in the cup-plate test using a mutant of *Escherichia coli* ATCC 10799 as the test organism
- Titrimetric determination of the acid produced in the tube test using *Lactobacillus lecihmannii* ATCC 7830.

Applications

Cyanocobalamin is used in the preparation of liquid and dry drug formulations of all kinds. In the animal feed industry, usually cobalamin concentrates are being used.

5.2.2.5 Biotin

Biotin forms long, colourless needles or a white crystalline powder. It is sparingly soluble in cold water, but more soluble in hot water and dilute alkalis. Biotin is sparingly soluble to insoluble in common organic solvents. Aqueous solutions of biotin are sensitive against the action of oxidants and UV light. In the presence of strong acids and concentrated alkalis, biotin is not stable. Biotin solutions are susceptible to mold growth.

Importance

Biotin is involved in a number of important metabolic reactions, probably as coenzymes. Deficiency symptoms are manifest as degenerative changes of the skin and pelt of various animal species such as rats, mice, chickens and pigs. In addition, degenerative processes of the muscles and various glands have been observed. Resistance against various infections is reduced.

Occurrence

Biotin occurs in nature very likely in all living cells, although usually in minute concentrations. In animal organs and in yeast, biotin is mainly contained in bound form. However, in vegetables, rice bran and in milk, it is present in free form.

Determination

Microbiological methods are suitable only for the detection of free biotin. We shall not go into the details of the method used for determination of biotin here since it is not within the perview of the unit.

Applications

Biotin is mainly used in the preparation of injection, and also in the manufacture of vitamin B complex and multi-vitamin preparations. It is used in the manufacture of baking yeasts.

5.2.2.6 Folic acid

Folic acid occurs as a yellow or orange-yellow, microcrystalline powder, almost without odour and taste. Water content of folic acid is up to 8.5%. Folic acid is very slightly soluble in water. Solubility increases with the temperature and the pH. Folic acid is sparingly soluble to insoluble in the usual organic solvents. The substance is without characteristic melting point, heating above 250°C will produce darkening and decomposition. Aqueous solutions of folic acid are not stable in the presence of reducing and oxidizing agents, heavy metal ions as well as sunlight and UV light.

Importance

In general, folic acid is known to be involved in a number of vital metabolic reactions.

Occurrence

Folic acid is an active principle widely occurring in the animal and vegetable kingdom. Richest sources are liver, dark green leafy vegetables, beans, wheat germ and yeast. Most dietary folates exist in the polyglutamate form which is converted in the small intestine to the monoglutamate form before absorption in the blood stream. Enzymes present in the liver catalyses the liberation of folic acid from these compounds. Bacteria, yeasts and molds contain abundant amounts of folic acid or its component 4-aminobenzoic acid; both these compounds stimulate their growth.

Determination

Reductive hydrolysis of folic acid produces 4-aminobenzoyl glutamic acid which is determined photometrically after diazotization and coupling with N-(1-naphthyl)-ethylenediamine.

In the microbiological assay, it is either by the turbidimetric growth measurement of *Streptococcus faecalis* ATCC 8043 or titrimetric determination of lactic acid produced by *Lactobacillus casei* ATCC 7469.

Applications

Folic acid is mainly used in the manufacture of dry drug formulations and also in the vitamin fortification of animal feeds.

5.2.2.7 Nicotinic acid (Niacin)

Niacin refers to both nicotinic acid and its amide derivative. Nicotinic acid occurs as white or almost white crystals or as a crystalline powder of the same colour without odour and is of weakly acid taste. Nicotinic acid is freely soluble in boiling water and sparingly soluble in water at about 20°C. Nicotinic acid is freely soluble with salt formation at low temperatures in acids and alkalis. The solubility of nicotinic acid in ethanol corresponds to that in water. Acetone and ether are also good solvents for nicotinic acid.

Importance

Nicotinic acid is successfully used in the therapy of a number of vascular disorders such as vascular spasms, angina pectoris, arthritis, hypertensive complaints, moreover as supportive therapy in migraine, headache and others. In the animals, Niacin is involved in reactions that generate energy from carbohydrate, fats and protein catabolites. It is essential for the synthesis of hormones.

Occurrence

Nictoinic acid occurs widely in the animal and vegetable kingdom in free as well as in bound form (in enzymes). Several animal organs such as liver, kidney and myocardium show a high nicotinic acid content. Yeasts and mushrooms are also very rich in nicotinic acid. In animals, it is predominantly found as nicotinamide.

Determination

The chemical methods of assay are based on colour reactions of pyridine. Nicotinic acid and nicotinamide are converted by cyanogen bromide into a derivative of the glutacone aldehyde, which is condensed with aromatic amines to form polymethine dyes (yellow colouring reactions).

The microbiological assay involves the titrimetric determination of lactic acid produced by *Lactobacillus arabinosus* ATCC 8014.

Applications

Nicotinic acid is mainly used in the vitamin fortification of flour, macaroni and noodle products. Independent of its vitamin efficacy, nicotinic acid is used in the meat industry, sometimes in combination with ascorbic acid to retain the colour in minced and unpickled meats.

5.2.2.8 Pantothenic acid (Calcium pantothenate)

Calcium pantothenate is a white, loose, faintly hygroscopic powder without odour and of bitter taste. It is easily soluble in water, glycerin, sparingly soluble in ethanol, acetone and ether; insoluble in chloroform and benzene. A 5% aqueous solution has a pH of 7.2-8.0. Pantothenic acid is stable under neutral conditions but is readily destroyed by heat in alkaline or acidic solution.

Importance

One of the active forms of pantothenic acid is coenzyme A, which is involved in numerous metabolic functions. It is involved in the synthesis of vital compounds like sterols, hormones, neurotransmitters, phospholipids, antibodies and in reactions that supply energy.

Occurrence

Pantothenic acid is a ubiquitous active principle occurring in free as well as in the bound form. In the bound form, pantothenic acid is incorporated into the coenzyme A which is an important compound that initiates several biological reactions in the living cells. Small amounts are synthesized in the intestines.

Determination

Hydrolysis of calcium pantothenate in acidic medium produces α,γ-dihydroxy-β,β-dimethylbutyrolactone, which reacts with hydroxylamine in the presence of alkalis to produce the corresponding hydroxamic acid. After addition of ferric chloride solution, the purple colour produced is measured at 500 nm.

The microbiological assay involves the titrimetric determination of lactic acid produced by *Lactobacillus arabinosus* ATCC 8014.

Applications

Calcium pantothenate is used in the preparation of drug formulations and the vitamin fortification of animal feeds.

Check Your Progress Exercise 2

1. Fill in the blanks:

(i) Vitamin B_{12} deficiency manifests as--

(ii) Vitmain B_{12} is present in --

(iii) Deficiency symptoms of biotin are manifested as --

(iv) Biotin occurs as ---in nature

(v) Folic acid is an active principle in --

(vi) --acts as a mediator in the methionine synthesis.

(vii) Nicotinic acid is used in the therapy of --

(viii) Nicotinic acid occurs in--

(ix) The determination of nicotinic acid is based upon---

(x) The active form of Pantothenic acid is which is involved in--

2. Give the applications of the following vitamins:

a) Vitamin B_{12}

----

b) Biotin

----

c) Folic Acid

----

d) Nicotinic Acid

----

e) Pantothenic acid

5.2.3 Vitamin C (Ascorbic acid)

Vitamin C, ascorbic acid is also called anti-scorbutic vitamin. Ascorbic acid occurs as white crystals or white crystalline powder without odour and of citric acid like taste. Turns pale yellow on prolonged storage. Ascorbic acid is easily soluble in water, soluble in methanol, ethanol and glycerin and insoluble in ether, chloroform, benzene, petroleum ether, fats and fatty oils. The pH values of aqueous ascorbic acid solutions are:

1% (w/v) solution is about pH 2.8; 5% (w/v) solution is about pH 2.5; 10% (w/v) solution is about pH 2.4; 20% (w/v) solution is about pH 2.2

Ascorbic acid reacts like strong, monobasic acid. The action of atmospheric oxygen as well as exposure to daylight and UV light causes rapid destruction of ascorbic acid in aqueous solutions. Ascorbic acid is also destroyed by the action of oxidizing agents and heavy metal ions and in the presence of alkalies.

Importance

Vitamin C is involved in redox processes in the organisms. It is possible, that vitamin C exerts its physiological function as a redox substance in combination with an enzyme group. Vitamin C affects the formation of the mesenchymal tissues, bones, cartilage and teeth. Vitamin C is implicated in the metabolism of aromatic amino acids. Also vitamin C promotes the conversion of folic acid into its active form, the citrovorum factor. While most animals are capable of synthesizing ascorbic acid themselves, man, monkeys and guinea pigs depend on the supply of ascorbic acid with their food.

Occurrence

Vitamin C (ascorbic acid) is an active ingredient present in any animal or vegetable cell which occurs in the plant in free form and also bound to protein as ascorbigen. Vitamin C amounts contained in the various plant and animal tissues differ considerably. All fresh fruits, various vegetables and also milk are important nutritional physiological carriers of vitamin C. Considerable vitamin C is lost by cooking, preservation, drying and storage of the food commodities.

Determination

Majority of chemical methods of determination is based on the rapid oxidation of ascorbic acid and therefore not too highly specific. Titration of ascorbic acid with 2, 6-dichlorophenolindophenol is one of the commonest methods.

Applications

Ascorbic acid is used for the preparation of various drug formulations and for the vitamin fortification of foods and beverages.

5.2.4 Vitamin D (Calciferol – vitamin D_2)

The main forms are Vitamin D_2 (ergocalciferol-plant origin) and vitamin D_3 (cholecalciferol-animal origin). Vitamin D_2 forms colourless, acicular crystals or a crystalline powder without taste and of only faint odour. Vitamin D_2 is easily soluble in either chloroform or benzene, ethanol, acetone and fatty oils and insoluble in water. Vitamin D_2 is sensitive against atmospheric oxygen. It is not stable either in the presence of oxidizing substances and oxygen carriers. Moreover, vitamin D_2 is destroyed by acids, metal ions as well as UV and visible light.

Importance

Vitamin D is mainly involved in the calcium and phosphate metabolism. It usually promotes absorption of calcium and inorganic phosphate from the intestine. It participates in the transport of calcium and phosphate and also in the deposition of these mineral substances in the organic bone matrix.

Occurrence

Cholecalciferol is synthesized in the skin by the action of ultraviolet light on 7-dehydrocholesterol which is widely distributed in animal fat. Vitamin D is relatively stable in foods. Storage, processing and cooking have little effect on its activity although in fortified milk upto 40% of added vitamin may cost as a result of exposure to light.

Determination

Spectrophotometric determination of the orange yellow colour developed with antimony chloride in chloroform, with an absorption maximum at 500 nm.

Applications

Vitamin D_2 is mainly used in the preparation of various drug formulations. For the animal feed industry, a mineral stable dry powder under the name of vitamin D_2 is available. In many countries, milk and milk products, margarine and vegetable oils fortified with vitamin D serve as a major dietary source of vitamin.

5.2.5 Vitamin E (DL-α-Tocopherol)

DL-α-Tocopherol is a yellow to red-brown, clear, viscous oil almost without odour which decolourise when exposed to light and air. DL-α-Tocopherol is soluble in ethanol, acetone, ether, chloroform, petroleum ether and in fats and fatty oils. It is insoluble in water. By the action of oxidants (such as oils and fats containing peroxide, atmospheric oxygen) DL-α-Tocopherol will readily lose its potency. This process is accelerated by irradiation. Contact with heavy metals should be avoided, if possible (catalytic effect on oxidation processes). Light, heat and oxygen are detrimental factors which reduces the stability.

Importance

Vitamin E has a pronounced antioxidizing effect. Because of this property, vitamin E decreases the basic metabolism of the tissues or the oxygen consumption and protects readily oxidizable compounds like vitamin A and carotenoids in the intestine and the tissues against oxidation. In the same manner, vitamin E also protects the easily oxidable unsaturated fatty acids. It also promotes utilization of these essential fatty acids and prevents the formation of toxic lipoperoxides which have a detrimental effect on tissues.

Occurrence

The tocopherols are widely found in animal and vegetable materials, like nuts and seeds. Considerable amounts are found in a number of vegetable oils, wheat and corn germs.

Determination

DL-α-Tocopherol is oxidized with ferric chloride and the ferrous ions formed are measured colorimetrially with the aid of α,α’-dipyridyl (bright red colour).

Applications

DL-α-Tocopherol is mainly used as an antioxidant in stabilizing edible oils and fats and fat-containing food commodities, pharmaceutical preparations and cosmetics.

5.2.6 Vitamin K (Menadione – Vitamin K_3, oil soluble)

Menadione is a yellow, lustrous, crystalline powder. It is easily soluble in benzene, soluble in fats and fatty oils. It is sparingly soluble in ethanol and chloroform and very sparingly soluble in water. Melting point is between 105 and 108°C. Menadione is not stable in the presence of acid as well as of alkalis and substances with alkaline reaction and in the presence of reducing agents. Exposure to light and ultraviolet light will decompose menadione with brown discolouration.

Importance

The site of action of vitamin K activity is the highly complex mechanism of blood coagulation. Due to its effect on prothrombin, vitamin K is also involved in the immunological processes as prothrombin is a component of that complement the blood fibre of which is raised by administration of vitamin K.

Occurrence

Vitamin K is found naturally in plants and vitamin K2 is synthesized by the bacteria in the intestines in humans. In nature, only two naphthoquinone derivatives with antihaemorrhagic action – vitamins K_1 and K_2 have been found so far. In addition, there are a number of synthetic naphthoquinone compounds with vitamin K activity. Of these, especially vitamin K_3 (menadione) and some esters of vitamin K_4 (menadiol), such as 2-methyl-1,4-naphthohydroquinone dibutyrate are distinguished by valuable therapeutic properties. Other dietary sources include green leafy vegetables, cabbage, lettuce, soyabeans, beef liver and green tea. Egg yolk, milk, butter and cheese also contain vitamin K.

Determination

Colorimetric determination of menadione in oily solutions with dinitrophenyl hydrazine.

Applications

Menadione is used in the preparation of drug formulations and vitamin K supplementation of feed mixes and infant formula.

Check Your Progress Exercise 3

1. Fill in the blanks:

(i) Vitamin D_2 is sensitive against---

(ii) The Vitamin D can be determined by--

(iii) Vitamin E loses in efficacy by---

(iv) Antioxidizing effect of vitamin E leads to---

(v) The destruction of ascorbic acid is caused due to--

(vi) One of the common methods to determine ascorbic acid is-----------------------------

----

(iv) The protein-bound form of vitamin C in plants and animal cells is --

(v) The Vitamin K derivatives which have valuable therapeutic properties are--

2. Give the roles of following vitamins in food industry:

a) Vitamin C

----

b) Vitamin D

----

c) Vitamin E

----

d) Vitamin K

5.3 MINERALS

We are all familiar with the term minerals. Definition of minerals, as it applies to food and nutrition usually refers to the elements other than carbon, hydrogen, oxygen and nitrogen that are present in food. All foods contain minerals in relatively low concentrations. Minerals play key functional roles in health and nutrition of humans. Ninety chemical elements occur naturally in the earth's crust. About 25 of them are known to be essential to life and thus are present in living cells. Since our food is ultimately derived from living plants or animals, we can expect to find these 25 elements in our food. The minerals in foods are usually determined by ashing or incineration. This destroys the organic compounds and leaves the minerals behind. Minerals, as you may recall studying earlier, are mainly classified into two categories. What are these categories? The next sub-section presents a brief summary for you to read and refresh your memory.

5.3.1 Classification of Minerals

Minerals can be divided into two main categories, namely, main elements (calcium, potassium, phosphorous, chlorine, sodium, magnesium) and trace elements (iron, zinc, copper, manganese and iodine etc). According to their biological roles, they may also be divided into essential elements that have known biological roles; non-essential elements with unknown functions; and toxic elements. There are 20 essential nutritive elements e.g. sodium, potassium, phosphorous, iron, calcium, chromium, zinc, selenium, magnesium, copper, tin, cobalt, manganese and fluorine. Non nutritive non toxic elements are boron and aluminium; and non nutritive, toxic elements are mercury, lead and cadmium.

What is the role of these substances? The nutritional and functional role of minerals is discussed herewith.

5.3.2 Nutritional and functional role of minerals in foods

Essential elements including the main elements and a number of trace elements fulfill various functions: as electrolytes, as enzyme constituents and as building materials in bones and teeth. In addition to their nutritional and physiological role, minerals contribute to food flavour. They activate or inhibit the enzyme catalyzed and other reactions. In some foods, minerals also affect the texture. Even though minerals are present in low concentrations, they often affect the physical and chemical properties of food because of their interactions with other food components. The functional role of few of the minerals are highlighted in tabular form herewith.

Table 5.2 Nutritional/Functional role of minerals

Minerals	Food Source	Nutritional Functional role
Aluminium	Low and variable in foods, component of some antacids and leavening agents	Possibly essential, evidence not conclusive, deficiency unknown. *Leavening agent:* As sodium aluminium sulfate (Na_2SO_4. $Al_2(SO_4)_3$) *Texture modifier*
Bromine	Brominated flour	Not known to be essential to humans. *Dough improver:* $KBrO_3$ improves baking quality of wheat flour. It is the most used dough improver.
Calcium	Dairy products, green	*Essential nutrient:* Deficiency leads to

	leafy vegetables, tofu, fish bones	osteoporosis in later life. Texture modifier: Forms gel with negatively charged macromolecules such as alginates, low-methoxy pectins, soy proteins, caseins, etc. firms canned vegetables when added to canning brine.
Copper	Organ meats, sea foods, nuts, seeds	*Essential nutrient:* Deficiency is rare. Catalyst: Lipid peroxidation, ascorbic acid oxidation, non enzymatic oxidative browning. *Colour modifier:* May cause black discoloration in canned, cured meats. *Enzyme cofactor:* Polyphenoloxidase. Texture stabilizer: Stabilizes egg white foams.
Iodine	Iodised salt, sea food, plants and animals grown in areas where soil iodine is not depleted.	*Essential nutrient:* Deficiency produces goiter and cretinism. *Dough improver:* KlO_3 improves baking quality of wheat flour.
Iron	Cereals, legumes, meat contamination from iron utensils and soil	*Essential nutrient:* Deficiency leads to anemia, impaired immune response, reduced worker productivity, impaired cognitive development in children. Excessive iron stores may increase risk of cancer and heart disease. Catalyst: Fe^{2+} and Fe^{3+} catalyse lipid peroxidation in foods. *Colour modifier:* Colour of fresh meat depends on valency of Fe in myoglobin and haemoglobin: Fe^{2+} is red, Fe^{3+} is brown. Forms green, blue or black complexes with poly phenolic compounds. Reacts with S^{2-} to form black FeS in canned foods. *Enzyme cofactor:* Lipoxygenase, cytochromes, ribonucleotide reductase, etc.
Magnesium	Whole grains, nuts, legumes, green leafy vegetables	*Essential nutrient:* Deficiency is rare *Colour modifier:* Removal of Mg from chlorophyll changes color from green to olive-brown
Manganese	Whole grains, fruits, vegetables	*Essential nutrient:* Deficiency extremely rare. *Enzyme cofactor:* pyruvate carboxylase, superoxide dismutase
Nickel	Plant foods	*Essential nutrient:* Deficiency in humans unknown. *Catalyst:* hydrogenation in vegetable oils – finely divided, elemental Ni is the most widely used catalyst for this process

Phosphates	Ubiquitous, animal products tend to be good sources	*Essential nutrient:* Deficiency is rare due to presence in virtually all foods. Acidulent: H_3PO_4 in soft drinks. *Leavening acid:* $Ca(HPO_4)_2$is a fast-acting leavening acid. *Moisture retention in meats:* Sodium tripolyphosphate improves moisture retention in cured meats. *Emulsification aid:* Phosphates are used to aid emulsification in comminuted meats and in processed cheeses.
Potassium	Fruits, vegetables, meats	*Essential nutrient:* Deficiency is rare. Salt substitute: KCl may be used as a salt substitute, may cause bitter flavour. *Leavening agent:* Potassium acid tartarate.
Selenium	Sea food, organ meats, cereals (levels vary depending on soil levels)	*Essential nutrient:* Keshan disease (endemic cardiomyopathy in China) was associated with selenium deficiency. Low selenium status may be associated with increased risk for cancer and heart disease. *Enzyme cofactor:* Glutathione peroxidase
Sodium	NaCl, MSG, other food additives, milk, low in most raw foods	*Essential nutrient:* Deficiency is rare; excessive intake may lead to hypertension. *Flavour modifier:* NaCl elicits the classic salty taste in foods. *Preservative:* NaCl may be used to lower water activity in foods. *Leavening agents:* Many leavening agents are sodium salts, e.g., sodium bicarbonate, sodium aluminium sulfate, sodium acid pyrophosphate.
Sulfur	Widely distributed	*Essential nutrient:* A constituent of the essential amino acids methionine and cystine. Sulfur amino acids may be limited in some diets. *Browning inhibitor:* Sulfur dioxide and sulfites inhibit both enzymatic and nonenzymatic browning. Widely used in dried fruits. *Antimicrobial:* Prevents, controls microbial growth. Widely used in wine making.
Zinc	Meats, cereals.	*Essential nutrient:* Deficiency produces loss of appetite, growth retardation, skin changes. ZnO is used in the *lining of cans* for proteinaceous foods to lessen

		formation of black FeS during heating. Zinc can be added to green beans to help stabilize the colour during canning.

From the table above, you would have got a fairly good idea about the functional role of minerals in foods in addition to their nutritional role in our body. Next, we will look at the bioavailability of minerals in foods.

5.3.3 Bioavailability of Minerals

It is well known that the concentration of a nutrient in a food is not a reliable indicator of its nutritional value. In other words, the entire quantity of the nutrient present in the food may not be utilized by the human body. *Bioavailability may be defined as the proportion of a nutrient in the ingested food that is available for utilization in metabolic processes*. In the case of mineral nutrients, bioavailability is determined primarily by the efficiency of absorption from the intestinal lumen into the blood. In some cases, the absorbed nutrient may be in a form that cannot be utilized. Bioavailability of mineral nutrients may vary from less than 1% for some forms of iron to greater than 90% for sodium and potassium. Chemical form of the mineral in food, formulation of chelates with minerals, redox activity of food components, mineral – mineral interactions and physiological state of the consumer are the factors that may influence the mineral bioavailability from foods. Processing the food can have an adverse effect on the minerals present in foods. What are these effects? We will dwell on this aspect in the next section, but first a word about how to estimate the mineral content in foods?

5.3.4 Estimation of minerals in foods

The minerals in foods are determined by ashing or incineration at temperatures in the region of 500°C following standard procedure. This destroys the organic compounds and leaves the minerals behind. Ash thus obtained provides an estimate of the total mineral content of foods. Minerals in the ash are in the form of metal oxides, sulphates, phosphates, nitrates and halides. Individual minerals are determined by dissolving the ash, usually in acid, and measuring the mineral concentration in the resulting solution. Atomic absorption spectroscopy is generally used to estimate the mineral concentration. Nuclear Activation Analysis-NAA is a more sensitive method.

5.3.5 Effect of processing on mineral content of foods

Minerals are comparatively stable under processing conditions such as heat, light, use of oxidizing agents and extremes in pH. But, minerals can be removed from foods by leaching or physical separation. It has been reported that milling of cereals causes considerable mineral loss. Minerals are mainly concentrated in the bran layers and the germ. Thus, removal of bran and germ during milling leaves pure endosperm, which is mineral poor. For example, when wheat is milled to obtain refined flour, the losses in mineral content are 76% (iron); 78% (Zinc); 86% (manganese); 68% (copper); and 16% (selenium). Similar losses occur during milling of rice and other cereals. Cooking in water would result in some losses of minerals since many minerals have significant solubility in water. In general, boiling in water causes greater loss of minerals from vegetables as against steaming. Canned foods may take up metals from the container: tin and iron from the tin plate, and tin and lead from the solder. For example, this occurs in canned acid foods such as fruit juices; canned foods having sulphur containing amino acids.

Check Your Progress Exercise 4

1. Fill in the blanks:

(i) The term `Minerals’ refers to the --- --- ------------------

(ii) Bioavailability may be defined as--- --- ------------------

(iii) Ash contains minerals in the form of--- ----------

(iv) ---is used to estimate the mineral concentration

(v) Bioavailability of mineral nutrients varies from ---------------------------to- ---

2. Give the functional roles of essential elements in the food industry.

----

3. Explain the effects of processing on mineral content.

5.4 LET US SUM UP

In this unit, you studied about different vitamin and minerals. Vitamins, as you would know, are of basically two types, fat-soluble (AD,E & K) and Water-soluble (B-complex and C) of these Vitamin B play a major role in the normal functioning and maintenance of biological processes. Both vitamin types are required for normal metabolism, growth and development and regulation of the cell function.

Next, we studied about different minerals and its classification. The nutritional and functional role of minerals in food was briefly discussed. Apart from these, certain other issues that were described included the concept of bioavailability, mineral estimation and processing effects on minerals in foods.

5.5 GLOSSARY

Acicular : narrow, long or pointed.

Amphoteric reaction : A double reaction possessed by certain fluids which have a combination of acid and alkaline properties.

Angina pectoris : A recurring pain or discomfort in the chest that happens when some part of the heart does not receive enough blood through narrowed, diseased coronary, arteries.

Antioxidants : A chemical compound or substance that is thought to protect body cells from damaging effects of oxidation.

Arthritis : An inflammation of a joint usually accompanied by pain, selling and stiffness, resulting from trauma infection, degenerative changes, metabolic disturbances or others

Atrophy : A wasting away from want of nourishment or to cause wasting due to disease of disuse

Bioavailability : This proportion of a nutrient in the ingested food that is available for utilization in metabolic processes.

Catalyst : A substance that increases/modifies the rate of a chemical reaction without being consumed in the reaction.

Chelates : To combine with a chemical compound to form a ring.

Cofactor : Inorganic ion or coenzyme necessary for the activity of an enzyme by forming a complex

Cornification : The conversion of squamous epithelial cells into a Keratinized horny material, such as hair, nails or feathers

Coupling : A connection between two things so they move together.

Decomposition : The act/ process of decay or dissolution consequent on the removal or alteration of some of the ingredients of a compound.

Esterification : A chemical reaction resulting in the formation of at least one ester product.

Flourescent : Emission of light during exposure to radiation from an external source.

Fortification : The addition of an ingredient for the purpose of increasing or improving the value of a product.

Hygroscopic : a substance that readily absorbs moisture, as from atmosphere.

Incineration : A treatment technology used to destroy waste by controlled burning at high temperatures.

Isoelectric point : The pH of a solution in which a protein has no net charge and does not migrate in an electric field.

Leavening agent : An organism or substance that when added to dough of flour and water causes it to rise by evolving carbon dioxide or other gases that become trapped as bubbles within the dough.

Mesenchymal tissues : Connective tissue, composed of star-shaped cells in an extracellular matrix.

Migraine : A vascular headache caused by blood flow and chemical changes in the brain leading to constriction of arteries supplying blood to the brain and release of certain brain chemicals, causing severe pain, stomach upset and other symptoms.

Miscible : Capable of being mixed; mixable

Oxidation : The act or process of oxidizing, or the state or result of being oxidized.

Pernicious anaemia : Condition caused by vitamin B_{12} deficiency and characterized by anaemia and spinal cord abnormalities, such as lesions of spinal cord, weakness, sore throat, numbness in the arms and legs, diarrhoea atc.

Prosthetic group : A tightly/covalently bound, specific non-polypeptide unit required for the biological function of some proteins

Redox Process : These are the electron transfer processes in which an oxidizing agent receives electrons and a reducing agent concedes electrons.

Stabilizer : A substance that renders or maintains a solution, mixture, suspension, or state resistant to chemical change.

Sterilization : The removal or destruction of all microorganisms, including pathogenic and other bacteria, vegetative forms and spores.

Thermostable : Unaffected by relatively high temperatures or capable of being heated to higher temperatures without loss of special properties.

Turbid : not clear; thick

Vascular Spasms : A sudden, brief tightening of a blood vessel. It can temporarily reduce blood flow to tissues supplied by that vessel.

5.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

(i) Atmospheric oxygen, oxygen carriers, oxidizing agents, metals ions and UV light.

(ii) Storage in cool place, under vaccum or inert gas in air-tight containers or sealed ampules.

(iii) Concentrates and oily solutions of the acetate and palmitate and their formulations

(iv) Yeasts, grain germs and rice polish

(v) Fortification of white flours with chemically pure vitamins of the B group.

(vi) Alkalis, materials giving alkaline reaction, strong reducing agents, metal ions and exposure to day light and UV light.

(vii) Pyridoxine, pyridoxal and pyridoxamine

2.

a) dry mixtures, coated tablets and capsules

b) drop solutions

c) drug formulations such as ampule solutions, drops and tablets

d) colour various food commodities such as baked foods, noodles and macaroni products, ice creams and soup mixes.

Check Your Progress Exercise 2

1.

(i) pernicious anemia

(ii) liver, spleen, thymus and muscles, intestine and streptomycin species

(iii) – degenerative changes of the skin and pelt of various glands.

- reduced resistance against various infections.

(iv) All living cells and animal organs and yeasts, vegetables rice bran and milk.

(v) animals and vegetable kingdom.

(vi) Vitamin B_{12}

(vii) Vascular disorders, migraine, headache, and others

(viii) Liver, kidney, myocardium, yeast and mushrooms

(ix) Colour reactions of pyridine

(x) Coenzyme A, metabolic functions

2.

(a) liquid and dry drug ascorbigen

(b) preparation of injections and manufacture of B-complex and multivitamin preparations

(c) dry drug formulations and animal feed

(d) vitamin fortification of flour macaroni and noodle products, retain colour of meat products

(e) drug formulations and vitamin fortification of animal feed.

Check Your Progress Exercise 3

1.

(i) atmospheric oxygen, oxidizing substances, oxygen carriers, acids, metal ions, daylight and UV light.

(ii) Spectrophotometry

(iii) Action of oxidants – oils and fats containing peroxide, atmospheric oxygen, irradiation, contact with heavy metals,

(iv) Decrease in basic metabolism of tissues or the oxygen consumption; protection or readily oxidizable vitamins in the intestines and tissues promotes utilization of essential fatty acids and prevents incidence of toxic lipoperoxides.

(v) Atmospheric oxygen, exposure to daylight and UV light, oxidizing agents, heavy metal ions and alkalis.

\- Titration with 36 – dichlorophenolindophenol

2.

(a) drug formulations and vitamination of foods and beverages.

(b) various drug formulations.

(c) anti-oxidant in the food commodities and pharmaceutical industries.

(d) drug formulations and supplementation of feed mixes.

Check Your Progress Exercise 4

1.

(i) elements other than carbon, hydrogen, oxygen and nitrogen that are present in foods.

(ii) The proportion of a nutrient in the ingested food that is available for utilization in metabolic processes.

(iii) Metal oxides, sulphates, phosphates, nitrates and halides

(iv) Atomic absorption spectroscopy

(v) Less than 1% to greater than 90%.

2. Calcium: Texture modifier;

copper: catalyst, colour modifier, enzymes cofactor and texture stabilizer;

Iodine: dough improver;

Iron: Catalyst, colour modifier, Enzyme cofactor;

Magnesium: colour modifier;

Manganese: Enzyme Cofactor;

Nickel: Catalyst; Phosphates: acidulant, Leavening acid moisture retention in meals, emulsification aid; Potassium: salt

Sodium: Flavour modifier, preservative, leavening agent;

Sulphur: Browning inhibitor and anti-microbial agent;

Zinc: Browning Inhibitor and stabilizer

3. Minerals are comparatively stable under processing conditions such as heat, light use of oxidizing agents and extremes in pH, boiling and milling of cereals causes considerable mineral loss.

UNIT 6 ENZYMES, PIGMENTS AND DIETARY FIBRE

Structure

6.1 INTRODUCTION

In this unit, we will learn about enzymes, natural pigments, colourings and their application in food science and biotechnology. Once again, while studying this unit, we request you to refer back to the unit on enzymes in Nutritional Biochemistry and Advance Nutrition course. The structure and properties of enzymes have been dealt in great details in unit 3, block 1 of Nutritional Biochemistry course. Look up the content given there. It forms the basis of understanding the applications and uses of enzymes in the food industry, as discussed in this unit.

Objectives

After studying this unit, you will be able to:

- discuss the history of enzymes and its uses in food industry,
- classify the enzymes,
- describe the biotechnological applications of enzymes, and
- explain the natural pigments and colours used in foods.

6.2 INTRODUCTION TO ENZYMES

In the earlier times, processes such as the souring of milk and fermentation of sugar to alcohol could only take place through the action of a living organism. In 1833, the active agent breaking down the sugar was partially isolated and given the name 'diastase', now commonly known as the enzyme amylase. Later, a substance which digested dietary protein was extracted from gastric juice and was called 'pepsin'. Subsequently, all active preparations were given the general name 'ferments'. The term ferment was gradually replaced by the name 'enzyme', proposed in 1878. Today, enzyme still forms a major subject for academic research. Enzymes are still widely used in industry, continuing and extending many processes which have been used since the dawn of history.

Enzymes, as you may already know, are biological catalysts. They increase the rate of chemical reactions taking place within living cells without themselves suffering any overall change. The reactants of enzyme-catalyzed reactions are termed 'substrates' and each enzyme is quite specific in character, acting on a particular substrate or substrates to produce a particular product or products.

Note, all enzymes are proteins. Many enzyme proteins lack catalytic activity in the absence of a non-protein component, called a 'co-factor'. In this case, the inactive protein component of an enzyme is termed the 'apoenzyme' and the active enzyme, including the cofactor, the 'holoenzyme'. The cofactor may be an organic molecule, when it is known as a 'coenzyme' or it may be a metal ion. When a cofactor is bound so tightly that it is difficult to remove without damaging the enzyme, it is sometimes called a 'prosthetic group'. With this basic introduction to enzymes, let us now learn about enzyme classification.

6.2.1 Classification of Enzymes

It has been a long tradition of giving enzymes names ending in 'ase'. The only major exception to this 'ase' is the *proteolytic enzymes*, whose names usually end with *'—in'*, *e.g. trypsin*. In the background of lack of consistency in the nomenclature, it becomes apparent as the list of known enzymes rapidly grew, that there was a need for a systematic way of naming and classifying enzymes. A Commission was appointed by the International Union of Biochemistry and its report, published in 1964 and updated in 1972, 1978, 1984 and 1992, forms the basics of the present accepted system which is summarized in box 1 herewith. A detailed classification of enzymes is presented in the unit 3, block 1 of the Nutritional Biochemistry course. We would want you to get it now and read it along with the study of this unit. You will see this will facilitate your understanding of enzymes.

Box 6.1

System of classification

The Enzyme Commission divided enzymes into 6 main classes, on the basis of the total reaction catalyzed. Each enzyme was assigned a code number; consisting of four elements, separated by dots. The first digit shows to which of the main classes the enzyme belongs, as follows:

First digit	*Enzyme class*	*Type of reaction catalyzed*
1	Oxido-reductases	Oxidation/reduction reactions
2	Transferases	Transfer of an atom or group between two molecules (excluding reactions in other classes)
3	Hydrolases	Hydrolysis reactions
4	Lyases	Removal of a group from substrate (not be hydrolysis)
5	Isomerases	Isomerization reactions
6	Ligases	The synthetic joining of two molecules, coupled with the breakdown of

	pyrophosphate bond in a nucleoside triphosphate

The system of the nomenclature and the classification of enzymes is based exclusively on the reaction that is catalyzed and does not consider their origin or multiplicity. Enzymes catalyzing the same reaction, but isolated from different species, will have varying amino acid sequences so that they may be distinguished by electrophoretic methods. They may have different sizes and net negative charges and they may even differ in their catalytic behaviour.

6.2.2 Structure of Enzymes

Since all enzymes are proteins, you will realize that knowledge of protein structure is clearly a pre-requisite to any understanding of enzymes. Yes, as you can see all proteins consist of amino acid units, joined in a series. You have already learnt about the structure of proteins, amino acids in Unit 4 in this block and in the Nutritional Biochemistry course. Look up the protein structure once again. As you can see all proteins consist of amino acid units joined in series.

Two distinct types of proteins are known: fibrous and globular proteins. Fibrous proteins are insoluble in water and are physically tough, which enables them to play a structural role. In contrast, globular proteins are generally soluble in water and may be crystallized from solution. They have a functional role in living organisms, *all enzymes being globular proteins.*

Based on the structure, enzymes can be classified as monomeric or oligomeric. Let's learn how the two types of enzymes differ from each other.

Monomeric enzymes

Monomeric enzymes are those which consist of only a single polypeptide chain, so they cannot be dissociated into smaller units. Very few monomeric enzymes are known and all of these catalyze hydrolytic reactions. In general, they contain between 100 and 300 amino acid residues and have molecular weights in the range of 13 kDa to 35 kDa. Some, for e.g. *carboxypeptidase A*, are associated with a metal ion, but most act without the help of any cofactor.

A number of monomeric enzymes are *proteases* (or proteolytic enzymes), i.e. they catalyze the hydrolysis of peptide bonds in other proteins. In order to prevent them doing generalized damage to all cellular proteins, they are often synthesized in an inactive form known as a 'proenzyme' or 'zymogen' and activated as required. Such enzymes include the *serine proteases*, so called because of the presence in the active site of an essential serine residue, i.e. a serine residue whose presence is essential for the enzymic activity. The serine proteases, chymotrypsin, trypsin and elastase, which are produced in an inactive form by the mammalian pancreas, form a closely related group of enzymes.

Other monomeric enzymes include*, pepsin,* like the pancreatic serine proteases, plays a role in the digestion of proteins eaten by mammals. It is called an acid protease because it functions at the low pH values found in the stomach. Peptide fragments are removed from the inactive form, pepsinogen, by the action of acid or other pepsin molecules to produce the active enzyme. Another acid protease found in the stomach is *chymosin (rennin).*

A group of *thiol proteases*, similar in structure to each other, are found in plants. These include *papain* from the papaya fruit and *ficain* from figs. Other thiol proteases, of different structures are found in bacteria and mammalian lysosomes. The essential cysteine residue in each of these enzymes plays a similar role to that of serine in the serine proteases.

Several exopeptidases, which remove terminal amino acid residues from polypeptide chains, are well known. Bovine pancreatic carboxypeptidase A, a monomeric enzyme containing one zinc ion per molecule, will break the peptide bonds linking C-terminal non-polar amino acids to the rest of the chain. It is produced when trypsin removes peptide fragments from the zymogen, procarboxypeptidase A. A very similar enzyme, carboxypeptidase B, which has specificity for C-terminal amino acids with basic side chains, is also secreted as a zymogen by bovine pancreas.

Oligomeric enzymes

Oligomeric proteins consist of two or more polypeptide chains, which are usually linked to each other by non-covalent interactions and never by peptide bonds. The component polypeptide chains are termed sub-units and may be identical to or different from each other, if they are identical, they are sometimes called protomers. Dimeric proteins consist of two, trimeric proteins of three and tetrameric proteins of four subunits. The molecular weight is usually in excess of 35000 Da. The vast majority of known enzymes are oligomeric, which include *lactate dehydrogenase, lactose synthase, tryptophan synthase and pyruvate dehydrogenase*

Check Your Progress Exercise 1

1. Fill in the blanks:

a) Enzymes are termed as catalyst because they---

b) The non-protein component of an enzyme is--------------- in which active part is--- -----------------------and non-active part is termed as---------------------------------

c) The system of nomenclature and classification of enzymes is based on-------------- ---

d) Two distinct types of proteins are------------------and---------------------- which differ in the property of ---

e) Proteases are synthesized in an inactive form as ------------------to prevent---------- ---

2. How can the enzymes be classified? Explain giving examples.

Having understood the classification of enzymes, let us move on to learning about the applications of enzymes in food industry.

6.3 BIOTECHNOLOGICAL APPLICATIONS OF ENZYMES

Although enzymes have been used in certain industrial processes for centuries, their precise role or even their identity was not known over most of this period. Often, they were utilized as components of intact cells, e.g. yeasts in the baking and brewing industries. The first enzyme to be made commercially available in a partially purified form was the acid protease, rennin (chymosin) as rennet, a crude preparation obtained from the fourth stomach of young calves, used to curdle milk in cheese production. In view of the varied problems faced, the trend has been towards increased utilization of microorganisms as sources of enzymes.

More recently, procedures involving recombinant DNA technology has been used to increase the yield of enzymes already produced by the microorganisms, e.g., β-galactosidase by *E. coli* or to produce completely different enzymes including ones normally synthesized by eukaryotic cells. These techniques may even be used to produce enzymes of modified structure from suitably modified or synthesized genes. This is termed as *protein engineering.* Once a suitable strain of a potential microorganism has been identified, the same may be grown to produce larger amounts of enzyme. Most enzymes obtained commercially from microbial fermentation procedures are hydrolases. These are usually extracellular enzymes.

This technology, which involves the industrial use of biological processes to develop new products, is termed as *biotechnology.* The technique employs modification in genes, which you may already know, is a section of deoxyribonucleic acid i.e., DNA. You can find detailed information on enzymes and recombinant DNA technique in Box 6.2. Read it carefully. But first let us look at the various uses of enzymes in food industry.

6. 3.1 Enzymes utilization in food industry

Enzymes may be used in industry as components of living cells or after isolation in free or immobilized forms. All of them may be referred to as *biocatalysts.*

The traditional use of yeasts in the baking and brewing industries arose, because they contain the enzymes necessary to bring in desirable attributes.

A. Baking Industry

In the baking of bread, the preliminary process involves the mixing of wheat flour (mainly starch and proteins) with yeast and water. Starch consists of D-glucose units linked by α-1,4 glycosidic bonds with α-1,6 bonds at branching points, the enzymes α-amylase and β-amylase present in the flour cleave some of the α-1,4 bonds, the eventual products being glucose, maltose (a disaccharide) and some oligosaccharides, which cannot be broken down further, because of the presence of α-1,6 bonds. Glucose and maltose can then be metabolized by the yeast, and carbon dioxide is formed, which disintends the protein framework of the dough, ready for baking.

B. Brewing Industry

Here, the main starting material is malt, produced by allowing barley seeds to germinate under moist conditions. The reserve starch is broken down by the amylase present to give, among other products, glucose and maltose. The grains may then be roasted to prevent further growth and to add flavour, after which the soluble material present is extracted by water to produce the wort. This is then acted upon by the yeast to produce ethanol by alcoholic fermentation of the glucose and maltose.

Bacterial α-amylase (from *Bacillus subtilis*), which is even more heat stable than wheat α-amylase, is of increasing importance in the brewing industry. In the industrial production of glucose from starch, the latter is first solubilized and partly degraded by bacterial α-amylase and then treated with fungal amyloglucosidase. Glucose may also be

obtained from cellulose-containing waste products by treatment with cellulose; as a further possibility, it may be produced together with galactose by the action of β-galactosidase (lactase) on lactose, which is present in whey and so is a major by-product of cheese manufacturing.

Invert sugar, a mixture of glucose and fructose, is produced from sucrose by the action of yeast invertase (β-fructofuranosidase), an enzyme which can only be extracted by disruption of the yeast cell wall. Invert sugar may also be produced from glucose by the action of glucose isomerase (bacterial or fungal), an enzyme now thought to be identical to xylose isomerase.

The clarification of cider, wines and fruit juices is usually achieved by treatment with fungal pectinases. The pectins of fruits and vegetables play an important role in jam making and other processes by bringing about gel formation. However, they cause fruit drinks to be cloudy by preventing the flocculation of suspended particles. Pectinases are a group of enzymes including polygalacturonases, which break the main chain of pectins.

C. Cheese Production

Cheese production involves the conversion of the milk protein, k-casein to paracasein by a defined, limited hydrolysis, catalysed by chymosin (rennin). In the presence of Ca^{2+}, paracasein clots and may be separated from the whey, after which the clot is allowed to mature under controlled conditions to form cheese.

You will further read in detail about the uses of enzymes in food industry in the Food Microbiology Course, unit 5.

Box 6.2 Enzymes and recombinant DNA technology

Recombinant DNA technology, also called as *genetic engineering* makes use of a variety of enzymes, particularly restriction endonucleases (from bacteria) and DNA ligases to insert extra genes into cells with the help of vehicles termed ‘vectors’. One important group of vectors is ‘plasmids’, which are small, circular, cytoplasmic molecules of DNA, acting as extrachromosomal genes in bacteria. It is possible to extract and purify plasmids and to insert extra genes into the circles. These altered plasmids can then be taken up again from the medium by the microorganism. Then as the bacterium is grown in culture, the inserted gene will be replicated together with the vector. The production of identical copies is termed as 'cloning. You will learn about cloning in the Nutritional Biochemistry course, unit 9, block 3 as well.

Another group of vectors are the variants of a bacterial virus known as λ phage. The phage DNA is about 45 kb long, of which the middle third has no role in the infection process and can be replaced by another piece of DNA of about the same length (again by means of restriction endonuclease and ligase enzymes) without affecting the ability of the phage to infect bacteria and be reproduced in abundance. Genes or gene fragments of about 15 kb length can be inserted and cloned in this way, in contrast to the limit of 10 kb when plasmids are used as vectors. Irrespective of the vector used to insert new DNA into bacteria, this DNA can specify the synthesis of a protein by transcription/translation, which enables in the large scale production of enzymes.

You have so far learnt about enzymes and its uses in food industry and biotechnology. Further, you would be surprised to learn that analysis of enzymes in foods can provide useful information regarding a process or condition. How? Read the next section and find out.

6.3.2 Enzymatic analysis in foods: applications in food industry

Did you know that the degree of bacterial contamination of foods or freshness of food, particularly, meat etc. can be determined through a simple enzymatic analysis in foods. Besides these, the other uses of enzymatic analysis are many.

In the food industry, the activity of certain enzymes may be determined before and after pasteurization/sterilization procedures to ascertain the efficient completion of the process.

For e.g. alkaline phosphatase and invertase present in milk are inactivated within the same temperature range as is required for pasteurization, so the activities of these enzymes at the end of the process gives an indication of its effectiveness.

Similarly, the degree of bacterial contamination of foods can be estimated by the assay of microbial enzymes not normally present in foods, for e.g. milk should contain small amounts of reductases, but bacteria produce large amounts of reductases. Reductases may be easily assayed, because they catalyze the reduction of methylene blue to colourless leuco-methylene blue under anaerobic conditions. A test strip (Bacto-strip) incorporating 2,3,4-triphenyl tetrazolium salts provides a convenient way of testing for the presence of bacteria, a red formazan dye being produced as a result of the action of reductase.

Enzyme assay may also be used to determine whether stored plant products are suitable for use as food commodities, for e.g. α-amylase should be present in relatively low amounts in stored wheat seeds. If there is sprouting/germination of a stored crop, then the α-amylase content increases. Once the flour has been produced, its amylase content may again be assayed to give an indication of the amount of starch breakdown which can be expected to take place when the dough is prepared.

The freshness of meat may be determined by the use of monoamine oxidase to detect amines formed during degradation. Besides, enzyme assay is used in the investigation of diseases in plants, for e.g. it has been found that an injury (either mechanical or pathogenic) results in a marked and localized increase in the activity of glucose-6-phosphate dehydrogenase, but not of glucose phosphate isomerase.

Enzyme assay is also used for research into such processes as the browning of plant products which poses problems during value addition. The browning process involves the cyanide-resistant uptake of oxygen, which oxidizes phenols to quinines resulting in the formation of dark melanins. In wine preparation, the concentration of malic acid is sometimes determined by a method involving malate dehydrogenase.

The discussion above highlighted the various applications of enzymes and enzyme analysis in food industry. With this we come to the end of our study about enzymes. Next we shall focus on pigments and natural colours in foods.

Check Your Progress Exercise 2

1. Name the enzymes that are used in :

a) Baking of bread --

b) Brewing ---

c) Clarification of fruit juices and wines--

d) Cheese production---

2. Define the following terms:

a) Genetic engineering

----

b) Biotechnology

----

3. Describe how enzymes assay is helpful in determining the extent of freshness in:

a) Wheat seeds

----

b) Milk

----

c) Meat

6.4 NATURAL PIGMENTS

What is a pigment? Scientifically, a chemical that can impart colour and is insoluble in the solvent in which it is used, is referred to as a 'pigment'. Well, you would agree that colour has a remarkable influence on food selection, consumption and overall enjoyment. Although the colouring of foods with natural compounds is considered to be desirable for various reasons, their use is limited at present. A few substances, notably the carotenoids, have been successfully incorporated into specific products, but natural colourants offer neither the range of colour nor the stability of synthetic dyes. Attempts to improve the situation have taken various forms. There has been an extensive search of the microbial, plant and animal kingdoms for pigments that possess both high tinctorial power/strength (a measure of the potential colouring power of a colourant) and stability, but so far, no exceptional candidates have emerged. The instability of the common natural colourants in food has been studied to seek the means of stabilization and the environment in which the pigments exist in nature, has been investigated for the same reason. Recent work on these approaches is reviewed, but any solution to the problem must be reconciled with the legislative and economic constraints governing the use of colourants in foods.

Currently, the use of natural colourants is limited due to their instability, low tinctorial power or price disadvantage. The trend towards natural ingredients in foodstuffs is continuing and this is evidenced by the consumer's acceptance of 'natural' foods and the various national regulations which completely or selectively ban artificial colours from food. Let us get to know a bit more about these natural colours used in foods.

6.4.1 Natural Colors Used In Foods

Natural colourants produced for use in an analogous way to the coal-tar dyes are crude extracts of pigments, which are basically unstable. The apparent stability of some food products owes more to the amount of pigment present than to the tinctorial power of the pigment itself. For example, beetroot even after prolonged cooking retains an attractive deep red colour, but the extracted pigment is unstable. Anthocyanin preparations have found use in some products, but their colour variation with pH has restricted their use, mainly to acidic products. However, in nature, the flavonoids (Flavanoids are antioxidant molecules found in plant sources such as fruit, flowers, roots, stems, tea, wine, grains and vegetables. They are often responsible for the beautiful coloring of plant structures) produce colours from white through yellow, red and blue to black at the pH of cell sap. The potential colouring power of flavonoids is, therefore, great.

Carotenoids are relatively stable and there is a sufficient demand to make complex chemical syntheses of 'nature-identical' carotenoids. Their colour range is limited to yellow/orange/red and they are naturally fat soluble, although water soluble forms are also available.

Chlorophylls are used as colourants in a range of foodstuffs and both natural chlorophyll (containing magnesium as the central metal ion) and 'copper chlorophylls' (copper substituted for magnesium) are available. Both chlorophyll and copper chlorophyll are manufactured in fat soluble and water soluble forms by selective retention or hydrolysis of the phytol side chain. Apart from these three plant pigments, there are others such as red beet extract (betanin), cochineal, turmeric extract and others which have found use in food. As alternates to the above, there has been a search among the plant, animal and microbial kingdoms for pigments which are stable under conditions prevailing in foods (i.e., pH of 2 to 8; temperature of -20 to 110°C; presence of additives and preservatives). Another approach has been to prevent the colour loss from foods. Both chemical and physical methods have been used to prevent destruction of natural colours in foodstuffs. As a means to achieve the desirable attributes of natural colours, it has been shown that biotechnological approaches appear to hold a lot of promise in the application of natural colours in foods. What are the sources of natural colourants? The next section details the sources of natural colourant.

6.4.2 Novel Sources of Natural Colourants

In the search for a colourant that has the properties desired for food use, practically every part of the biosphere has been investigated. The following are some of the sources:

A. Microbial sources

Production of materials by microbial cultures has several advantages. The rapid growth of microbes cuts the production time to a matter of days and the process lends itself to a continuous operation. Compared to plant or animal sources, the production is flexible and can easily be controlled. Microbes produce a variety of colourants such as chlorophyll and carotenoids as well as some unique pigments. By incorporating suitable genetic material into selected microbes (recombinant DNA technology), it may be possible to produce pigments of choice, both qualitative and quantitative approaches. Most of the reports of food colourants from microbial sources involve *Monascus* species, particularly *Monascus purpureus*, followed by *Rhodotorula* species, *Chlorella*, *Nocardia* and red algae. Often, instead of extracting the pigment from *Monascus*, a few researchers have attempted in adding the whole coloured substrate to foods for the purpose of providing colouration. Careful control of the culture conditions selectively improves the yield of various pigments elaborated by the specific microbial culture.

Although cultivation of microorganisms for the production of food colourants has attractions, these must be measured against the financial legislative and user constraints. It is desirable, that the microbial cultures which produce colourants would have to be proved pathogen free and also free from any toxic components. There is still no substantial evidence to suggest that the pigments from *Monascus* are superior to other natural colourants. Potentially its orange or red colour is suitable for food use, its long usage in Oriental foods is also in their favour and the property of reacting with amino-containing compounds suggests that they could easily be incorporated into food systems. They appear to be stable in the pH range 2-10 although below pH 2, precipitation occurs on standing.

B. Animal sources

The most common animal pigments of use as food colourants are those based on the haem structure. In nature, haem is combined with proteins and occurs mainly as haemoglobin and myoglobin. Although the appearance of these two components is attractive when they are oxygenated (bright red), the colour produced on heating is typically brown (e.g. cooked meat) and removal of oxygen in the native state gives rise to the blue/purplish colour of venous blood. The colour changes are due to the oxidation state of the central iron atom in the haem portion of the molecule and the nature of ligands surrounding the iron atom. The bright red colour of freshly cut meat is due to oxygen binding as a ligand to the iron atom which is in the ferrous state. However, oxygen does not bind very strongly and it is known that other ligands bind more strongly, stabilizing the molecule and preserving the red colour.

Ligands suggested for the stabilization of haem pigments are imidazole (and its derivatives), S-nitrosocysteine and nitrite. While searching for alternatives to nitrite in the preparation of fish sausages, imidazole, 5(4)-aminoimidazole-4(5)-carboxamide (AICA) and various amino acid derivatives were used and found to impart colour to the finished product. Imidazole gave a red/pink colour with an orange tint, which faded on the surface of the produce unless an antioxidant was present. Animals appear to be a poor source of colourants.

C. Plant sources

Although there is a multitude of colours in the plant kingdom, their extraction and use in food systems is not an easy task. Unless the colourants have some outstanding advantage, e.g. good stability in food or very high tinctorial power, it is generally not worth continuing. Assuming that the source provides a colourant with exceptional properties, further considerations need to be taken into account. A major problem with the plant sources is their availability, as most plants are seasonal. Many of the plant sources listed in literature would require major planting programmes to provide sufficient material for production purposes. Another consideration is the cost of extraction and processing, which is obviously minimal for an aqueous extraction, but will be greater, if organic solvents are used and subsequently recovered.

Usually, the natural food colourants from plant sources are classified into 5 types: Anthocyanins, Betalaines, Carotenoids, Chlorophylls and Curcumin. Literature has been well documented, with a lot of research work going into varied aspects of colourants from the above plant sources. A variety of fruits, vegetables and flowers have also been studied as potential sources of colourants. One of the novel sources has been tissue culture of grape varieties. The callus induced from the anther of grape plants is transplanted to a liquid culture medium and cultured aerobically. Pigment is then extracted from the culture which can be manipulated to give maximum colour yield during growth, by adding various chemicals to the medium or irradiating with light.

Colourant production from by-products has the advantages that there is normally an abundance of the source, it is cheap and in a defined state. Further, treatment of the by-product reduces waste and enhances the profitability of a process. The citrus industry produces large amounts of waste and the extraction of colourants from cold pressed citrus oils has been described. The colourants (presumably carotenoids) are extracted from the oil by solvent and purified.

The volume of patent literature concerning novel microbial, animal and plant sources of colourants indicates the potential of the field, but only a few of them are workable. Many pigment extracts are no better than the presently available natural pigments and the availability and/or economics of the source material or extraction procedure causes rejection of others.

Stability of natural colourants is one of the major issues in food industry. There is a lot of interest and work being undertaken to ensure stability of natural colourants in food. Are these efforts successful? Let’s get to learn more about this issue. Microbial sources are also important like *Rhodotorula* and *Monascus* but needs to be commercialized.

6.4.3 Stability of Natural Colorants in Foods

Many attempts have been made to retain colouration by adding chemicals or modifying processing conditions. Ascorbic acid has been claimed as a stabilizer for natural colourants and conversely, its presence has been cited as the cause of pigment degradation. With anthocyanins, ascorbic acid sometimes has a protective effect, e.g. it absorbs available oxygen and thus prevents oxidation of the anthocyanin. On other hand, enzyme action on ascorbic acid results in the release of hydrogen peroxide, which oxidizes and decolourises the anthocyanins. Hence, addition of ascorbic acid to food products will not necessarily stabilize the colour.

The effect of metal ions on the colour and/or stability of food products has been the subject of several investigations. Traces of some metal ions, notably copper and iron, have a catalytic effect on the oxidation of ascorbic acid, which in turn leads to degradation of anthocyanins. Anthocyanins containing an *ortho*-dihydroxy grouping, chelate metal ions, which may alter the colour of the anthocyanin.

Red anthocyanin pigments from miracle fruit were isolated and tested in carbonated beverages, in combination with the organic acids. Pigments degradation occurred with all acids and malic acid caused the most rapid degradation. In grape juice, malic acid caused the greatest increase and also increased the colour stability as did valeric acid. Malonic and oxalic acids increased the colour initially, but fairly rapid decolourization occurred on storage.

Light does accelerates the degradation of natural colourants, especially anthocyanins, but is of secondary importance when compared to the losses of anthocyanin due to the effect of heat and/or oxidation. Anthocyanins had doubled resistance to sunlight fading when flavonoid sulphonates were used as co-pigments. While additives can improve the colour stability of natural pigments in specific cases, there are no general guidelines for their use.

We conclude our discussion noting the fact that ascorbic acid and metal ions can stabilize colour in some situations, but their use in unfavourable conditions may actually increase the rate of degradation. Some organic acids may be beneficial, but others enhance instability and the concentrations and/or nature of inorganic salts used to improve the stability of natural colourants are such as to limit their application.

Well, then are there any stabilized forms of natural colourants! Read and find out.

6.4.4 Stabilized forms of natural colourants

The mimicking of the native environment in which a natural colour exists is just one way of producing a stabilized form. In this case, the method of stabilization can be considered 'natural' whereas some of the modifications can be synthetic. The major emphasis has been on the stabilization of flavonoids and porphyrins. The present use of flavonoids as food colourants is limited to anthocyanin extracts from grape processing. These preparations are largely unsuitable for food use by themselves. A few of the following have been selected, as they appear feasible methods of stabilization within the constraints of retaining natural status:

Complex formation: Anthocyanin occurs naturally as complexes which are relatively stable. Studies on pectin/anthocyanin complexes may be useful.

Co-pigmentation: In formulating a product containing anthocyanin colourants, the inclusion of a co-pigment would augment and stabilize the colour.

Condensation: This seems the most likely way of producing acceptable, natural colourants for the reasons stated previously. Considerable research to study the production of the polymeric colours and their stability in food products needs to be carried out.

Chlorophyll is the porphyrin most widely used as a natural colourant. Its widespread occurrence in photosynthetic tissue and its breakdown character have prompted many investigations concerning stabilization of the molecule. Loss of magnesium follows denaturation of the protecting protein in the chloroplast. Several processing techniques to minimize chlorophyll loss involve alkaline blanching and soaking media. Attempts to stabilize chlorophyll have centered on the substitution of the normal magnesium ion.

Despite a wide search of novel sources throughout the world, attempts to find a naturally occurring pigment with all the desirable qualities of a food colourant have not been so successful on a commercial angle. Besides, the problem of securing an adequate supply of the successful colourant is a big question posed to the food industry. The stabilization of natural colours in foods is an extremely complex process and although some success has been there, each application needs to be looked into individually.

Check Your Progress Exercise 3

1. Fill in the blanks:

a) A pigment is---------------------------

b) Colour in foods has a remarkable influence on --

c) Naturally-occuring colourants have limited use because of ---------------------------- ---

d) The flavonoids produce colours such as---

e) Chlorophylls, as food colourants are manufactured by---------------------------------

2. Name natural food colourants obtained from:

a) Microbial sources--- ---

b) Animal sources-- ---

c) Plant sources-- ---

3. Discuss the effect of following on stability of enzymes:

a) Ascorbic acid

----

b) Organic acids

----

c) Metal ions

----

d) Light

----

4. Mention a few methods of stabilization of natural colourants

----

6.5 LET US SUM UP

In this unit, you have learnt about enzymes, which are known as biological catalysts. All enzymes are proteins, which take part in various chemical reactions occuring within the living cells without themselves suffering or undergoing any chang.e do you remember the terms ‘co-factor, ‘apo-enzymes’ and ‘holoenzyme’?

Co-factor is a non-protein component; apo-enzymes, the inactive protein component of an enzyme and holoenzyme is the active protein component

After, this, you also studied about the classification, functions and properties of enzymes. Finally, the various biotechnological aplications of enzymesin food industry and recombinant dna technlogy were discussed.

Use of colours and pigments, derived from natural and esynthetic source,s in food industry was described alongwith their stabiized forms as colourants.

6.6 GLOSSARY

Biotechnology **:** The industrial use of biotechnological processes, whereby the living organisms are used to develop new products.

DNA **:** Deoxyribonucleic Acid is a large molecule that contains genetic coding information within each cell.

Dye **:** A dye is a chemical that can impart colour and is soluble in the solvent in which it is used.

Flavanoids **:** Flavanoids are antioxidant molecules found in plant sources such as fruit, flowers, roots, stems, tea, wine, grains and vegetables. They are often responsible for the beautiful coloring of plant structures. Some 4000 flavanoids have been found. There are four main groups of flavanoids; 1) flavones, 2) flavanones, 3) catechins, and 4) anthocyanins. It is the flavones and catechins that appear to be important flavanoids in oxidation defenses.

Gene **:** A section of DNA which provides the genetic information needed to make one protein.

Porphyrins **:** Porphyrins are a ubiquitous class of naturally occurring compounds with many important biological representatives including hemes, chlorophylls, and several others.

Tinctorial strength **:** A measure of the potential colouring power of a colourant

6.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

a) They increase the rate of chemical reactions within living cells without themselves suffering any overall change.
b) Cafactor; apoenzyme, holoenzyme
c) The reaction that is catalyzed
d) Fibrous; globular; solubility in water
e) Zymogens/proenzyme; damage to all cellular proteins

2. Based on structure, enzymes can be classified into monomeric enzymes and oligomeric compounds.

- Monomeric enzymes: Enzymes which consist of only a single polypeptide chain, so they can't be dissociated into smaller units, for example, carboxypeptidase A, pepsin, chymosin etc.
- Oligomeric enzymes: Enzymes which consist of more than one polypeptide chain for example, lactate dehydrogenase, pyruvate dehydrogenase, tryptophan synthase.

Check Your Progress Exercise 2

1.

a) α-amylase and β-amlylase
b) Amylase
c) Pectinases
d) Chymosin/Rennin

2. a) Genetic engineering or recombinant DNA technology, involves the use of a variety of enzymes, such as restriction endonucleass and ligases to insert extra genes into cells with the help of vectors.

b) The technology which involves the industrial use of biological processes to develop new products.

3. a) determination of α-amylase, content: an increase indicates sprouting/ germination of stored wheat;

determination of reductase content: an increase indicates presence of bacteria

b) Determination of alkaline phosphatase and invertase: activity level of these enzymes indicate the effectiveness of pasteruization.

c) Determination of amines by the use of monoamine oxidase.

Check Your Progress Exercise 3

1. a) A chemical that can impart colour and is insoluble in the solvent in which it is used.

b) Food Selection, Consumption, Enjoyment

c) Instability, Low Tinctorial Power, Price

d) White through yellow, red and blue to black at pH of cell sap.

e) Selective retention or hydrolysis of the phytol side chain.

2. a) Monoscus sp., Rhodotorula sp., Chlorella, Nocardia and Red Algae

b) Ligands of Haem Pigments – Imidazole, S- Nitrosocysteine and Nitrite

c) Anthocyanins, Betalaines, Carotenoids, Chlorophyll, Curcurmin

3. a) It results in the release of hydrogen peroxide which oxidizes and decolorizes the natural colourants.

b) These have a catalytic effect on the oxidation of ascorbic acid which leads to degradation and alteration of colour of the natural colourants.

c) These degrade the pigments and rapidly decolorizes them on storage.

d) It accelerates the degradation of natural colourants.

4.

- Complex formation
- Co-pigmentation
- Condensation

UNIT 7: SOLS, GELS AND EMULSIONS

Structure

7.1 INTRODUCTION

Foods are generally complex materials. The properties of their components determine the quality of food. The food components are in the form of solids, in solutions or in the form of colloids - sols or emulsions. These undergo various physical and chemical changes when exposed to different conditions. Knowledge of the scientific principles of these changes is necessary to understand and control the changes occurring in foods during the various aspects of food handling. We shall discuss these scientific principles governing the physical and chemical properties of foods with special emphasis on colloidal systems in this unit.

Objectives

After studying this unit, you will be able to:

- define colloids and enlist the types of colloidal dispersions
- understand properties of colloidal systems that help in distinguishing them from solutions
- classify colloidal systems
- differentiate between sols, suspensions and gels
- define foams and discuss their application in food preparation
- explain the types of emulsions, their formation and stability

7.2 COLLOIDS, COLLOIDAL SYSTEMS AND APPLICATIONS OF COLLOIDAL CHEMISTRY TO FOOD PREPARATIONS

Foods contain a high percentage of water in which other nutrients present are dispersed. The existence of the colloidal state was first recognized by Thomas Graham (1850), the father of colloidal chemistry. He classified the organic compounds present in foods into two categories:

- Colloids
- Crystalloids

What is the difference between the two categories? Let's find out.

The word colloid, you may be interested to know, is derived from the Greek word "kolla" meaning "glue" and is defined as a system containing particles of size from one millimicron to 0.1 micron (10^{-6} to 10^{-4} mm). *Colloids* are compounds with large molecular weights, which form dispersions only with water. e.g. starch, proteins, glycogen, agar-agar.

Crystalloids, on the other hand, are compounds with small molecular weights, which can form true solutions. e.g. sugars and amino acids.

Figures 7.1 and 7.2 illustrates the colloidal range of particle size.

Figure 7.1: Colloidal Range of Particle Size

Figure 7.2: Size of Colloidal particles vs Water molecules

Solids, liquids and gases may be dispersed in water to form either solutions or colloids. Let us learn what the difference between the two is.

A *solution* is a homogenous mixture of two or more different substances. For example salt in water form a solution. This means that the dissolved substances (i.e. salt which is called the solute) and the medium in which they are dissolved (i.e. water which is the solvent) are uniformly distributed throughout the whole of the solution.

A *colloidal system, on the other hand,* is a heterogeneous system. The material that forms the base of the system is called *the dispersion medium* or *the continuous phase*. The material that exists in the colloidal condition is called the *dispersed medium or the discontinuous phase*. All three states of matter- gaseous, solid and liquid – may be obtained in the colloidal condition. Let us get to know more about colloids and colloidal system by learning about their classification.

7.2.1 Classification of Colloidal Systems

Thomas Graham referred to colloids as the study of sub microscope dispersion. According to him, it dealt with the dispersed systems of a definite size. Dispersions are classified on the basis of the size of the particles. The particles are dispersed through out the solvent in the form of molecules or ions (molecular dispersion) and it is a one phase system with molecules having dimensions below 1 nm. If the particles range in size from 1 mm to 0.5 mm, they can remain dispersed for a long time without precipitation and constitute a *colloidal system*. When the size of the dispersed particles is more than 0.5 mm it is termed *coarse dispersion or suspension.*

Colloidal systems are not restricted to the dispersion of a solid in liquid. Each of the three states of matter - gaseous, solid and liquid – can be dispersed in a medium which may be gaseous, liquid or solid. Accordingly, colloidal systems can be classified based on the physical state of the two phases present: the dispersed phase and the dispersing medium Systems with two phases can occur in eight different combinations, as highlighted in Table 7.1 presenting the classification of colloidal systems.

Table 7.1 Classification of colloidal systems

Dispersed Phase	Dispersing Medium	Name	Examples
Liquid	Gas	Fog	Aerosol sprays
Solid	Gas	Smoke	Smoked fish
Gas	Liquid	Foam	Whipped cream, meringue
Liquid	Liquid	Emulsion Oil in water Water in oil	 Milk, french dressing Margarine
Solid	Liquid	Sol	Whey, skimmed milk, starch suspension
Gas	Solid	Solid froth, foam	Bread, *idli*, candy floss
Liquid	Solid	Liquid inclusion	Gelatin, jellies, fruits, vegetables, meat products
Solid	Solid	Solid sol	Candies

Note: mixtures of gases do not form colloidal mixtures. They are solutions.

Depending upon the relative affinity of the dispersed phase for the dispersion medium, colloidal dispersions are, further divided into two classes.

- lypophilic (water loving colloids)
- lypophobic (water repelling colloids)

If the affinity between the dispersed phase and the medium is high, the dispersed phase is said to be lyophilic (solvent loving) or hydrophilic, in the case of an aqueous dispersion. Gelatin dispersed in water is an example of a lyophilic colloidal system. Other examples of hydrophilic colloids are biopolymers such as seaweed gums, pectic substances and proteins and hydrophilic complexes found in skim milk, egg yolk and brewed coffee.

If the affinity of the dispersed phase to go into or to remain in colloidal dispersion is slight, the dispersed phase is said to be lyophobic (solvent repelling) or hydrophobic when the medium is water. Oil dispersed in water as in the case of butter and margarine, is an example of a lyophobic system. Lyophobic colloids are mainly the aqueous dispersions of inorganic substances rarely recountered in food systems.

After having understood the concept and classification of colloids, let us learn about the properties of colloidal systems.

7.2.2 Properties of Colloidal Systems

Colloidal systems exhibit certain unique characteristics that help in distinguishing them from solutions. We will briefly review these properties now.

A. Tyndall Effect

One of the best ways to distinguish a solution from a colloidal dispersion is to use a strong beam of intense light. As the beam passes through a colloidal dispersion, it leaves a bright definite path, as the result of scattering or diffusing of light rays by their deflection from the surface of colloidal particles. This is known as *Tyndall effect* and is shown in the Figure 7.3. The particles may not be visible, but their presence and motion may be detected by the nature of the reflections. An important property of a colloid is this movement of the colloidal particles, brought about by the bombardment of thousand of molecules in the gas or liquid in which they are suspended. This molecular movement of the colloidal particles is known as the *Brownian movement* and is shown in the Figure 7.4.

Figure 7.3: The Tyndall Effect

Figure 7.4: Brownian Movement

B. Electric Charge

Colloidal particles are electrically charged. Some colloidal particles carry a positive charge (+), others a negative charge (-). The ionic charge is the same for all the charged particles in a given mass of material. This is why colloidal particles remain in suspension: particles with like charges do not clump together because they are repelled by one another as illustrated in the Figure 7.5.

Figure 7.5: Similarly charged colloidal particles deflect each other by electrical repulsion.

C. Adsorption

Colloidal particles attract and hold to their surfaces the molecules of various gases, vapors and other matter with which they come into contact. This phenomenon is called adsorption. Adsorption plays a very important part in the character of the colloid .By adsorption the particles acquire an electric charge which governs the stability of the colloid. The phenomenon of adsorption finds widespread application in food preparations. For e.g. a too salty soup stock may be made more palatable by the addition of egg white, which when cooked, will gather and hold the salt on to the surface of its particles and settle down to the bottom of the soup vessel.

D. Imbibition

The ability of colloids to pick up water and swell when they come in contact with water is called imbibition. Imbibition is usually accompanied by the evolution of heat and the added materials such as acids and alkalis have a marked effect on the degree of swelling.

E. Viscosity and Plasticity

Various degrees of viscosity and plasticity are encountered in colloids. Viscosity may be described *as resistance to pouring. Plasticity* is the property of solids that enables them *to hold their shape under small pressure*.

Colloidal systems range in degree of viscosity and plasticity according to the following environmental factors:

- Temperature affects the viscosity of a colloid. Generally, its viscosity decreases as the temperature increases. For e.g. milk becomes less viscous at high temperatures; such colloidal gels as gelatin and agar are less viscous at high temperatures than low ones.

- The viscosity of a colloid also increases with the concentration and aggregation of dispersed particles. For e.g. cream becomes more viscous when there is an increase in the number and aggregation of fat particles in it.
- Increased amounts of protein solids also bring amount an increase in viscosity. Thus the viscosity of custard is related to the amount of egg protein dispersed in the liquid.

In our discussion above, we highlighted the properties of colloids. Next, we shall focus on solutions and their properties. But first, attempt the exercises presented in the Check Your Progress Exercise 1. This will help you recapitulate what you have learnt so far.

Check Your Progress Exercise 1

1. Define colloids.

   ----

2. Differentiate between colloids and crystalloids.

   ----

3. What do you understand by the terms 'dispersion medium' and 'dispersed medium'?

   ----

4. Fill in the blanks :

Dispersed Phase	Dispersing Medium	Name	Examples
-------------	Gas	Fog	Aerosol sprays
Solid	-------------	Smoke	Smoked fish
-------------	Liquid	Foam	Whipped cream
Liquid	-------------	Emulsion Oil in water Water in oil	 Milk Margarine
Solid	Liquid	-------------	Whey
Gas	Solid	-------------	Bread, *idli*
Liquid	Solid	-------------	Gelatin, jellies, fruits, vegetables, meat products
Solid	Solid	-------------	Candies

7.3 DEFINITION AND PROPERTIES OF SOLUTIONS

Solutions, as you learnt earlier, are a homogeneous mixture of two or more different substances. This means that the molecules of the dissolved substances (solute) and the medium in which they are dissolved (solvent) are uniformly distributed throughout the whole of the solution. Solubility is the *amount of solute that can be dissolved in a given amount of solvent at a given temperature*. The effect of temperature on solubility varies with solutes. Increasing temperatures increases the solubility of some solute but has no effect on the solubility of others.

The concentration of a solution is the amount of solute dissolved in a specified amount of solvent or solution. When the concentration reaches a point when no more solute can dissolve in a solvent at a particular temperature, the solution obtained is said to be *saturated.* If a saturated solution of a solid is prepared at or near the boiling point of the solvent, on cooling the solid crystallize out e.g. sugar. Although fully cooked, sometimes the crystals may not separate out as in the case of fondant. Such a solution holds more solute than can normally be present at the same temperature. This solution is said to be *super saturated*. Supersaturated solutions are unstable and become more unstable as the degree of super saturation increases. Crystals do form ultimately when the solution becomes fairly cool, but the nature and size of the crystal varies. The phenomenon is of importance in sugar cooking. Different types of Indian sweets are prepared using this physical property of sugar solution.

Several properties of solutions are particularly important in food preparations. Amongst these are colligative properties, such as vapour pressure, boiling point, freezing point and osmotic pressure. Colligative properties are *the properties of solution which depend on the number of molecules present and not on their chemical nature are known as*. Let us understand these properties of solutions and their applications.

A. Vapour Pressure

The intermolecular forces in a liquid prevent most molecules from escaping from the surface. However, due to molecular collisions, some molecules have sufficient kinetic energy to escape from the liquid. This causes the evaporation of the molecules into the gaseous state. Any liquid, therefore, has above its surface, a certain amount of material in the form of vapour. Vapour molecules move in all directions. Some of the liquid get condensed. When the rate of evaporation and condensation are equal, an equilibrium is established. *The pressure exerted by vapour above the liquid when equilibrium exists is vapour pressure.* The vapour pressure is temperature dependent.

When a solid is dissolved in a volatile solvent the vapour pressure of the solution is less than the vapour pressure of the pure solvent because of the presence of solute molecules. In a solution, the number of solvent molecules at the surface is reduced and therefore the rate of evaporation is less than for the solvent. The extent of lowering is proportional to the number of molecules of solvent compared with the total number of solvent plus solute molecules. For e.g. when equal quantities of sucrose and sodium chloride are dissolved in a known amount of water at constant temperature, the lowering of the vapour pressure of water by sodium chloride is twice as much as that of sucrose, because sodium chloride contains twice as many of number of icons as the number of sucrose molecules in the solution.

B. Boiling Point

There are certain properties of solutions which are directly connected with vapour pressure and one of it is boiling point. You must have observed that water boils at a temperature of 100^{o}C. This is because a liquid boils when its vapour pressure is equal to external pressure. The normal boiling point (BP) refers to *an external pressure which is equal to the atmospheric pressure (760 mm Hg)*, which for water is 100^{o}C. With an increase is pressure, the boiling point increases, e.g., the boiling point of water at 770 mm is 100. 37^{o}C. You must have noticed that in a pressure cooker the water boils at 121^{o}C at 103 kg/kilo pascal, for this a greater pressure must be overcome and thus the boiling point can be elevated. Conversely, the boiling point can be lowered at a reduced atmospheric pressure as in high altitudes i.e. if you boil potatoes at a hill station, it will take longer time to cook as compared to the planes. For every 290 m increase in altitude above sea level, the boiling point of water is lowered by 1^{o}C.

This property of water is useful in the processing of foods, such as jams, jellies, syrups, confectionary etc. which are liquids at higher temperatures.

C. Freezing Point

The freezing point of a material is the temperature at which it changes from a liquid to a solid. A liquid freezes when its vapour pressue is equal to the vapour pressure of its solid. The freezing point of water is 0^{o}C.

You can modulate the freezing point of water by dissolving a non-ionizing solute in it. For e.g. a mole of sodium chloride or calcium chloride could depress the freezing point of water by 3.72^{o}C and 5.58^{o}C.

The practical importance of this is that a mixture of ice, water and salt gives freezing mixtures. Ice and water alone are in equilibrium at 0^{o}C, but if salt is added, some ice will melt in order to reduce the temperature to the new equilibrium position. This principle is used in making home-made ice. The freezing point of milk is 0.53^{o}C. Its freezing point is determined by its soluble constituents, lactose and salts, present in it. Since these soluble components vary in milk only slightly, the freezing point remains almost constant. This makes it possible to determine any dilution of milk. Addition of 1% by volume of water to milk rises the freezing point by approximately 0.0055^{o}C.

D. Osmotic Pressure

Osmosis, as you may already know, refers to the flow of solvent into a solution, or from a more dilute solution to a more concentrated solution, when the two liquids are separated from each other by a semi-permeable membrane. The membrane contains minute pores through which the solvent molecules can travel. The phenomenon of osmosis causes a change in the relative volume of the two liquids separated by the semipermeable membrane. The volume of the solution that becomes more dilute increases. Osmotic pressure is the pressure required to prevent that increase in volume or osmosis. Unlike solutions, colloids have little or no osmotic pressure. Hence, there is no passage of colloidal particles through animal membranes or cellulose walls.

The phenomenon of osmosis occurs in food. For e.g. when you stew fruits, the fruit increases in size, as the water flows with the fruit tissues. When the sugar concentration becomes higher than that of the fruit, the fruit will shrink due to the passage of water through the skin of the fruit into the syrup.

E. Viscosity

Viscosity, as you may already know, is associated with fluid flow. It is the internal friction which tends to bring to rest portions of the fluids moving relative to one another. This is measured in relation to some standard viscosity, generally of water at 25^{o}C. A number of factors affect the viscosity of a fluid; for instance, large changes take place due to temperature.

Viscosity determination is useful in the study of consistency of foods. Viscometric measurements are made in food industry for the study of food structure. Viscosity has an effect or heat transfer during pasteurization in the preparation of certain food materials, such as fruit juices. Viscosity is measured by viscometer.

F. Specific Gravity

The density of a substance is defined as mass per unit volume. The density of a substance is a characteristic property and has a definite value at a given temperature and pressure. The density of one substance in relation to the density of another material (e.g. water) is known as specific gravity. Therefore, specific gravity is the weight of a given substance referred to the weight of an equal volume of water at a definite temperature.

The specific gravity of foods, depend upon this components. The specific gravity of milk, for e.g., is greater than that of water. The average specific gravity of milk is 1.032 (at 15.5^{o}C); it ranges from 1.027 to 1.035. If the fat content of milk increases, the specific gravity decreases (upto to 0.93) and if the non-fat components increase, the specific gravity increases.

The importance of specific gravity, is utilized in the purchase of products like syrups, jams, jellies, milk (especially when whole milk is adulterated by addition of water) cream, ice-cream and alcoholic beverages. Specific gravity indicates the amount of air incorporated into the products (lightness of products), such as shipped cream, egg white foam, creamed shortening and cake batter.

Check Your Progress Exercise 2

1. Define the following terms:

a) Solubility

----

b) Concentration

----

c) Boiling point

----

d) Osmosis

----

e) Specific gravity

----

2. What do you understand by the term 'colligative properties'?

----

3. The vapour pressure of a solution depends on the number of solvent molecules. Explain how?

----

4. How can you modulate boiling point and freezing point of a solution?

----

5. Explain the role of surfactants in a solution.

In the last two sections, we learnt about colloids, solutions and their properties. Next, let us look at some of the colloidal systems such as sols, suspensions, emulsions etc. We start with sols, gels and suspensions.

7.4 SOLS, GELS AND SUSPENSIONS

What are sols? *A colloidal system in which solid particles are dispersed in a liquid is referred to as a sol*, to distinguish it from a true solution. In a true solution, the substances separate into molecules and ions that disperse homogenously throughout the volume of the solvent. But when a protein such as gelatin is dispersed in water, the solution-like mixture that results is a sol. Examined under a microscope, the individual protein particles are large enough to be distinguished from the dispersion medium.

Sols resemble liquids in their main physical properties – that is, they flow and they do not show rigidity of form. However, when a sol assumes a rigid form, it is referred to as a *gel*. There is no distinct line of separation between a sol and gel; infact some sols become gel by increasing the concentration of dispersed solids or micelles. A typical sol is a fluid whereas a typical gel has a certain amount of rigidity. The difference between a sol and a gel has been illustrated in Figure 7.6.

Figure 7.6: Difference Between a Sol and a Gel

During sol -gel transformation, a three dimensional network is formed by the interlocking of dispersed particles. The liquid phase is entrapped in the interstitial areas of this structure. When this happens, the sol loses its fluidity and becomes a gel. The change from sol to gel may be brought about by a change in the concentration of dispersed phase or a change in temperature .Gelatin dispersed in hot water is a sol, but when cooled it becomes a rigid, transparent gel. Other examples of sols that turn to gels are fruit jellies and custards.

Many gels lose liquid upon standing and the gel structure shrinks. *This is called weeping or syneresis*. The liquid that collects around a glass of fruit jelly or a dish of custard is an example of syneresis. Let us learn more about the properties of sols and gels.

7.4.1 Properties of Sols

Sol, you learnt earlier, is *a solid liquid dispersion with solid or semi-solid particles dispersed in a continuous liquid phase.* For e.g. starch in cold water. Sols exhibit characteristic optical properties. They may have an opaque or clear appearance to the naked eye and when viewed under a microscope, but the dispersed particles are sufficiently large to scatter and polarize the incident light to some extent. This is known as the *Tyndall effect*. You have learnt about the properties of colloids earlier. These properties are basic to sols.

When you view a sol through an ultra microscope, you will observe that colloidal particles appear to be in a state of rapid and irregular motion called the brownian movement. You may recall reading about the Brownian movement earlier under the properties of colloids. The movement is caused by the constant bombardment of the dispersed particles by the molecules of the dispersion medium. The smaller the size of the colloidal particles, the more vigorous is its Brownian motion.

In a sol possessing a continuous aqueous phase, the colloidal particles have an electrically charged surface. The ionized groups of proteins and phosopholipids can be the sources of the charges. In the presence of a small quantity of dissolved electrolyte, sol particles selectively adsorb ions of one type from the solution.

The adsorption of ions by colloidal particles is a major factor in stabilizing a colloidal dispersion, since the colloidal particles in a given system have the same charge they repel each other and hence the tendency to coalesce is reduced. Addition of salts to a sol causes precipitation. Charged particles have strong attraction for the polar water molecules and therefore are hydrated, probably having a complete envelop of water molecules.

Addition of salt helps in the withdrawal of water from the hydrated surfaces of the particles and this helps precipitation. Sols, unlike solutions, have low osmotic pressure. Thus, they cannot pass through animal membranes or through cellulose walls in plants. In lyophobic sols, there is little interaction between the dispersed phase and the dispersion medium. Consequently, properties like viscosity and surface tension of such sols are the same as these of the dispersion medium at the same temperature. In the lyophilic sols, owing to the salvation of the dispersed phase, there is difference in properties. The viscosity of lyophilic sols is greater than that of the dispersion medium and is increased marked by a decrease in temperature or an increase in particle concentration. At particle concentration greater than 20 percent, sols may exhibit elasticity.

7.4.2 Gels and its Properties

You already know that sol is free flowing liquid at room temperature, when it becomes relatively firm, it is called a *gel*. There are a number of factors that affect the strengths, elasticity and brittleness of the gel such as concentration of the jelling agent (particulates), salt content, pH and temperature. Polysaccharides, proteins or colloidal complex particles, such as caseinate micelles form gels at levels of 10% or less. Gums, pectin and gelatin form gels at levels of 1% or less. Salts and pH influence gel formation adversely or favourably depending upon the concentration. By the reduction in the number of charged particles, by the adjustment of pH or addition of salt, a sol can be transformed into a gel. Addition of sugar which competes with water in the continuous phase helps gel formation when used in the proper portion. Change in temperature has an effect on gel formation; low temperatures reduce the mobility of the colloidal molecules in the sol and increase the viscosity. This condition facilitates gel formation.

The rigidity of gel changes with time leading to *syneresis*, which involves release of water and contraction of gel volume. The amount of liquid released varies with the type of gel and the conditions under which it is prepared.

After gels, it is the turn of suspensions. What are suspensions? How do they differ from sols? Let's find out.

7.4.3 Suspensions

Sol, we learnt is a colloidal system, in which solid particles are dispersed in a liquid. When the particles of a solid are separated into large aggregates of particles and dispersed in a liquid, the food system is referred to as a *suspension.* In a suspension, the particles tend to sink to the bottom of the mixture if they are heavier than the liquid but rise to the top if they are lighter. A mixture of flour and water is an example of a mixture in which the particles are heavier than the liquid. If it is stirred and heated, a suspension of this kind will change to a gel.

So it must be clear to you that both sol, suspensions are solid and liquid dispersions. You may recall reading earlier that colloidal system may also exist as gas and liquid dispersion, liquid in liquid dispersion etc. next, let us learn about gas and liquid dispersions.

7.5 FOAMS

Consider the following example. Take some liquid in a glass and agitate or shake it vigorously. What do you observe at the top of the liquid. Yes, a foam is formed. Foams are also considered colloidal dispersions. Foams are dispersions of gas or air bubbles in a liquid. Foam is created by agitation of a liquid with a consequent entrapment of air in the liquid film. Foam consists of more or less stable liquid-air interfaces, the air cells being surrounded by liquid films that constitute the continuous phase. The foaming properties of liquids depend on their viscosity and low air-liquid surface tension. The gas bubbles are separated from each other by liquid walls called films or camellia, which are elastic. The diameter of the foam bubbles range from about 1 mm to several centimeters. Depending on the bubble size and wall thickness, dense or light foams are formed.

The foams frequently used in cookery are whipped cream, ice cream, cake, bread, meringues, milk froth and gelatin. Food foams contain large amounts of entrapped gas. They have an extensive surface area between the gaseous and liquid phase, a higher concentration of the solute at the surface than in the bubble liquid, and walls which are rigid and elastic and reflect light so that they have an opaque appearance.

Let us learn in more details about how the foams are formed? Formation of a foam is dependent on a foaming agent in the continuous phase prior to dispersion of gas. The foaming agent must be adsorbed at the surface to reduce surface tension and provide a distinct surface layer which resists the coalescence of gas bubbles. Surface active lipids, glycosides, proteins are used as a foaming agent.

There are two basic methods in the formation of foams i.e. *whipping and condensation*. *Whipping* is the most common method used as it forms bubbles by cutting the surface and introducing air into liquid. Repeated action makes the bubbles progressively smaller and creates a fine dispersion which is foamy and light in texture. In the *condensation method* a pressurized solution is suddenly released to expand the number of gas bubbles which their ripe through the liquid. In this method, the size of the bubbles become larger with time and cannot form even textured foam. Factors such as surface tension, iso-electric point, solubility of surfactant and low vapour pressure affect the formation of foam.

What about foam stability? Foam stability can be determined by two factors i.e. *drainage and bubble size.* The volume of the liquid drained due to gravitational forces when foam is left to stand for some time (20-30 minutes) indicates stability of the foam. The greater the drainage the less stable is the foam and also the larger the size of the bubbles in a foam. In food industries undesirable foams may be formed. This is overcome by using antifoaming agents? What are these agents? We will find out.

7.5.1 Antifoaming Agents

In food industries, undesirable foams may be formed such as in concentration of fruit juices, coffee extracts, vegetable oils and syrups or in fermentative processes. This leads to loss of a product and reduced rate of processing. Antifoaming agents such as silicon oils (water insoluble dimenthy, polysiloxames) are used in the food industry. They spread as a monolayer and displaces the stabilizing foam film, resulting in the thinning of the bubble walls and can cause bursting.

In this section we have looked at gas and liquid dispersions. Next, an insight into liquid and liquid dispersion is presented.

7.6 EMULSIONS

You may have eaten Mayonnaise. Some of you may also know how it is made. Mayonnaise is a liquid in liquid dispersion, in fact a true emulsion. A true emulsion represents a colloidal dispersion of one liquid in another when both liquids are mutually immiscible. Emulsions exhibit the characteristics of colloidal systems, the particle of the dispersed phase being about 0.1 mm. The liquid in which the dispersion takes place is called the *continuous phase*.

A food emulsion is basically a two phase system consisting of a liquid, such as oil, wax or essential oil and water. An emulsion has 3 parts – dispersed phase, continuous phase and or emulsifier which is a surface active agent that decreases interfacial tension and forms physical barriers around each droplet to impede or present their coalescence. Emulsions are basically of two types:

- Oil in water (o/w), and
- Water in oil (w/o)

The oil in water emulsion consist of lipid droplets dispersed in water e.g. milk, cream, ice cream, mayonnaise, salad dressing (Figure 7.7). The water in oil emulsion is made up of water droplets dispersed in oil e.g. butter, margarine.

Figure 7.7: oil in water emulsion

Food emulsions must have the appropriate appearance (colour + opacity), texture (viscosity, plasticity and oiliness) and flavour for acceptance. Let us learn how the emulsions are formed next.

The most common method of preparing an emulsion is by mechanically dispersing one liquid phase in another by formation of small droplets. This takes place by a beater blade. A stable emulsion is not formed by merely mixing of the liquids. When the emulsion is left to stand, droplets in the dispersed phase coalesce due to surface tension. It is possible, however to stabilize an emulsion by adding a suitable substance termed emulsifier. How this is done? Let's find out in the following text.

Emulsions can be stabilized by the use of emulsifiers, finely divided particles adsorbed at the interface and water dispersible hydrocolloids. Emulsifiers may be in the form of proteins, gums, gels fatty acids and phospholipids. Materials used as emulsifiers have an electric charge opposite to that of the material to which they are added. The emulsifier reduces the interfacial tension existing between the water and the oil, thus making them less repellant to each other. This can be accomplished because one end (polar end) of the molecule of the emulsifier is soluble in water and the other end (non polar end) is soluble in oil (Figure 7.8). This permits a film to form around each tiny drop of oil that prevents the drops from running together.

Figure 7.8

There are many emulsifiers which are present in nature such as phospholipids e.g. lectin which is present in egg yolk which acts as a natural emulsifier in stabilizing mayonnaise emulsion. Hydrocolloids, such as plant gums and gelatin, act as stabilizers in oil-in-water emulsions by increasing the viscosity of the continuous phase or sometimes by forming a strong interfacial film around droplets of the dispersed phase. Lecithin, alginates, plant and seed gums, and cellulose derivatives, such as carboxymethyl-cellulose and hydroxypropyl methyl/cellulose gums are used as stabilizers.

Emulsions may also be stabilized by a process known as *homogenization*, in which the size of the dispersed fat globules is greatly reduced to more or less uniform diameter by application of considerable force. This prevents the fat globules from coalescing.
We will stop our discussion on emulsions here.

Check your progress Exercise 3

1. Fill in the blanks:
   a) Sols resemble liquids in their main physical properties – that is, they …………and they do not show ……………………………………………………
   b) The process of loss of liquid from gels causing their shrinkage is called………………………………………………………………………………..
   c) Emulsions are of two types namely ………………… and ………………………
   d) Mayonnaise is an example of…………………. in ……………………emulsion.
2. Differentiate between sols and gels, giving examples.

   ----
3. List a few factors that affect properties of a gel.

----

4. Define the following terms:

a) Suspension

----

b) Foam

----

c) Emulsions

----

d) Food emulsifiers

----

5. How are foams formed? What are the factors affecting foam formation?

----

6. How can emulsions be stabilized?

7.7 LET US SUM UP

Let us summarize all that we studied in this unit.

A colloidal system is a heterogeneous system consisting of two phases- the dispersed phase and the dispersing medium. Each of the three states of matter i.e. gaseous, solid and liquid can be dispersed in a medium which may be gaseous, liquid or solid. Eight classes of colloidal dispersions can be formed from the three states of matter. Gases may be combined with solids or liquids in colloidal dispersions, but mixtures of gases form solutions not colloids. Colloidal particles are in motion and are electrically charged. The colloid's property of adsorption makes it useful in cookery. Colloidal systems may be lyophilic or lyophobic.

Sols and suspensions are both solid in liquid dispersions with solid or semi-solid particles dispersed in continuous liquid phase. In a suspension, particles tend to separate, rising if lighter than the liquid and sinking if heavier. Gels are rather rigid colloidal systems.

Foams are colloidal dispersions of gas or air bubbles in a liquid. A true emulsion is a colloidal dispersion of two mutually immiscible liquids. An emulsifier aids stabilization of emulsions. Homogenization in which particle size is reduced also stabilizes emulsions.

7.8 GLOSSARY

Brownian movement **:** movement of the colloidal particles, brought about by the bombardment of thousands of molecules in the gas or liquid in which they are suspended.

Coalesce **:** come together and form one mass.

Food emulsifiers **:** surface active agents consisting of hydrophilic and hydrophobic components.

Interface **:** boundary between a liquid-liquid or a solid-liquid junction.

Interfacial Tension **:** the tension at liquid/liquid or liquid/ solid interfaces.

Lyophilic sols **:** sols formed spontaneously when the dry coherent material is brought in contact with the dispersion medium.

Lyophobic sols **:** sols that cannot be formed by spontaneous dispersion in the medium. They are thermodynamically unstable.

Specific gravity : weight of a given substance referred to the weight of an equal volume of water at a definite temperature.

Surface tension : forces causing a reduction in the surface area.

Surfactant : a substance which lowers the surface tension of the medium in which it is dissolved.

Syneresis : loss of liquid from gels upon standing and the shrinkage of gel structure.

Tyndall effect : a property exhibited by a colloidal dispersion, where a strong beam of intense light leaves a bright definite path through a colloidal dispersion.

7.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Colloids are the compounds with large molecular weights, which form dispersions only with water e.g. starch, proteins, glycogen and agar-agar.

2. Colloids are compounds with large molecular weights, which form dispersions only with water. e.g. starch, proteins, glycogen and agar-agar while Crystalloids are compounds with small molecular weights, which can form true solutions. e.g. sugars and amino acids.

3. The material that forms the base of a colloidal system is termed as dispersion medium or the continuous phase. While the material that exists in the colloidal condition is called as the dispersed medium or the discontinuous phase.

4.

Dispersed Phase	**Dispersing Medium**	**Name**	**Example**
Liquid	Gas	Fog	Aerosol sprays
Solid	Gas	Smoke	Smoked fish
Gas	Liquid	Foam	Whipped cream
Liquid	Liquid	Emulsion Oil in water Water in oil	 Milk Margarine
Solid	Liquid	Sol	Whey
Gas	Solid	Solid froth	Bread, *idli*
Liquid	Solid	Liquid inclusion	Gelatin, jellies, fruits, vegetables, meat products
Solid	Solid	Solid sol	Candies

Check Your Progress Exercise 2

1.

a) Solubility is the amount of a solute that can be dissolved in the given amount of solvent at a given temperature.

b) Concentration is the amount of solute dissolved in a specified amount of solvent or solution.

c) An external pressure which is equal to the atmospheric pressure is the boiling point.

d) Osmosis is the flow of solvent in the solution or from a more dilute solution to a more concentrated solution when the two liquids are separated through a semi-permeable membrane.

e) Specific gravity is the density of one substance in relation to the other material.

2. Properties of solution which depend on the number of molecules present and not on their chemical nature are known as colligative properties.

3. When a solid is dissolved in the volatile solvent, the vapour pressure of the solution becomes less than that of a pure solvent because of the presence of solute

molecules. The extent of lowering is proportional to the number of molecules of solvent compared with the total number of solvent and solute molecules. Hence showing that vapour pressure depends on the number of solvent molecules.

4. Boiling point: by modifying the pressure

   Freezing point: by dissolving a non-ionizing solute in the solution.

5. Surfactants or the surface active agents are used to reduce the surface tension between the polar and non-polar groups of a solution. These agents are absorbed at the surface of a solution.

Check Your Progress Exercise 3

1.
   a) flow; rigidity of form
   b) syneresis
   c) oil in water and water in oil
   d) oil in water emulsion

2. Sol is a colloidal system in which the solid particles are dispersed in a liquid. When a sol assumes a rigid form, it is referred to as gel. Examples of sols that turn to gels are fruit jellies and custards.

3. Concentration of the jelling agent, salt content, pH and temperature are the factors that affect the properties of a gel.

4.

a) Suspension is the separation and dispersion of the particles of a solid into large aggregates of particles in a liquid e.g., a mixture of flour and water.

b) Dispersions of gas or air bubbles in a liquid is referred to as foam for e.g., whipped cream, ice cream, cake, bread and gelatin.

c) Emulsion is a colloidal dispersion of one liquid in another when both liquids are mutually immiscible e.g., milk, cream, mayonnaise, salad dressing.

d) The surface active agents consisting of hydrophilic and hydrophobic moieties are the food emulsifiers e.g., phospholipids and proteins.

5. There are two methods of foam formation. These are discussed as follows:

- Whipping: The most common method, as it forms bubbles by cutting the surface and introducing air into the liquid. Repeated action makes the bubbles smaller and creates a finer dispersion, which is foamy and light in texture.
- Concentration: A pressurized solution is suddenly released to expand the number of gas bubbles. The size of the bubbles becomes larger with time and cannot form even textured foam.

The factors affecting foam stability are:surface tension, isoelectric point, solubility of surfactant and low vapour pressure.

6.

- Use of natural stabilizers such as lectin; hydrocolloids such as plant gums and gelatins; plant and seed gums; cellulose derivatives.
- Homogenization

UNIT 8: PROPERTIES OF FOOD

Structure

8.1 INTRODUCTION

In the previous unit, we learnt that foods are generally complex materials. The food components are in the form of solids, in solutions or in the form of colloids - sols or emulsions. The properties of these components determine the quality of food.

The quality of a food product, you would realize, is also usually assessed by means of human sensory organs, the evaluation being called 'sensory' or 'subjective' or 'organoleptic'. Here, in this unit, we shall study about various sensory attributes of food. What characteristics make a food attractive and appealing? How does appearance and colour of a food affect our choice? Does smell has a role to play in making a food choice? Do mouth-feel and finger-feel contribute to food acceptance? All these attributes of a food product come under what we refer to as quality of foods. In this unit, we will learn about these quality attributes of food.

Objectives

After studying this unit, you will be able to:

- describe the quality attributes of food
- understand the characteristics influencing food choices and
- discuss what is rheology and its usefulness in foods.

8.2 INTRODUCTION OF QUALITY ATTRIBUTES OF FOOD

In India, seasonal fruits and vegetables are grown in plenty, and are available in their respective seasons in abundance. While choosing these fruits/vegetables what are the factors that we look in for? Yes, colour, wholesomeness, gloss, degree of ripeness, smell, taste, textured defects etc. are some of the factors on the basis of which we select or choose an item. These factors in sum can be thought of as "quality". *Quality has been defined as a 'degree of excellence and includes such things as taste, appearance and nutritional content. It is the composite of characteristics that have significance and which help in making the product acceptable. '*

When we select foods and when we eat, we use all our physical senses, including sight, touch, smell, taste and even hearing. When the quality of a food product is assessed by means of human sensory organs, the evaluation is said to be 'sensory' or 'subjective' or 'organoleptic'. Sensory quality is a combination of different senses of perception coming into play in choosing and eating a food.

Each time a food is eaten, a judgement is made. A wide range of vocabulary is used to describe sensory characteristics of food products, such as odour, taste, appearance, texture. These sensory characteristics of food products are highlighted in Table 8.1.

Table 8.1: Vocabulary used to describe sensory characteristics of food products

Odour	Taste	Appearance	Texture
Floral	Sweet	Heavy	Brittle
Rotten	Cool	Flat	Rubbery
Perfumed	Bitter	Fizzy	Short
Acrid	Zesty	Crystalline	Gritty
Musty	Warm	Wet	Clammy
Fragrant	Hot	Cuboid	Soft
Scented	Tangy	Fragile	Stodgy
Pungent	Sour	Dull	Bubbly
	Sharp		Sandy
	Rich		Tacky
	Salty		Tender
			Waxy
Odour and *taste* work together to produce a *flavour*. Following words may be used to describe either odour or taste of food products: Bland, Rancid, Tart, Acidic, Strong, Citrus, Milky, Spicy, Tainted, Weak, Savoury.		Following words may be used to describe either *appearance* or *texture* of food products: Firm, Flaky, Crisp, Fluffy, Dry, Crumbly, Lumpy, Smooth, Hard, Mushy, Sticky, Soft, Gummy, Chewy	

Food quality, as such, can be divided into three main categories i.e.

i. Appearance factors

ii. Textural factors

iii. Flavour factors

Let us see what these categories include.

(i) Appearance can be judged by the eye. Appearance factors include such things as size, colour, uniformity, absence of any defect, shape, wholesomeness, different forms of damage, gloss, transparency and consistency. For e.g. scrambled egg with a very dry surface is not acceptable. Fudge with a glossy surface is rated high. Similarly, quality of a fish can be ascertained by the brightness of the eyes of fish. In addition to giving pleasure, the colour of a food is associated with other attributes, such as ripeness of fruits like banana, tomato, mango, papaya etc. can be assessed by the colour. Burnt toast or chapati is likely to be rejected in anticipation of scorched bitter taste. Therefore, colour is used as an index of maturity for a number of foods. It is also associated with the flavour and texture and in some foods, with its nutritive value (e.g. Carotene or Pro-Vitamin A). Appearance covers not only colour but also the shape, size, greasiness, transparency, brightness and so on, all of which must match consumer's expectations of that food or product. Therefore, the foods have to pass the sight test first before they can be screened by other sensory organs. In many instances we can see consistency and so it is considered a textural quality attribute. For example, 'a thin boiled chocolate syrup, a thick or thin tomato sauce'. Similarly, size can be used as an indirect indicator of other attributes, such as maturity, e.g. small peas etc. are less mature and more tender than big ones. Also, size helps in obtaining a more uniformly sized product, prevents wastage and gives rapid production and a high product quality.

(ii) Texture may be assessed through touch or mouthfeel. When the food is placed in the mouth, the surface of the tongue and other sensitive skin reacts to the feel of the surface of the food. Textural factors, therefore, include assessment through handfeel and mouthfeel such as firmness, softness, juiciness, chewiness and grittiness. The texture of a food is often a major determinant of how little or well we like a food. The range of textures in foods is very great, and a deviation from an optimum or typical texture is a quality defect. We expect chewing gum to be chewy, crackers and potato chips to be crisp and steak to be compressible and shearable between the teeth. While buying bread, we squeeze bread as a measure of texture which indicates the degree of freshness. Refractometer is used for measuring texture.

(iii) Flavour factors include both sensations perceived by the tongue, which include sweet, salty, sour and bitter tastes and aromas perceived by the tongue and nose, respectively. Flavour is a combination of both taste and smell (aroma or odour), and is largely subjective, and therefore, hard to measure. *Bland, rancid, tart, acidic, strong, citrus, mild, spicy, tainted, weak and savoury are a few words that are used to describe either odour or taste of food products as highlighted* in table 8.1.

Flavour is also influenced by colour and texture. We associate certain flavours with certain colours. For example, cherry, raspberry and strawberry flavours, although are colourless compounds, we associate them with colour because in nature they occur in food of a typical colour. Similarly, texture can be also mislead evaluation of flavour. To site an example, when you are asked to judge two identical samples of gravies or soups differing in their consistencies, it is very likely that the thicker gravy would be accepted better because of its richer flavour, although it has been thickened with a tasteless starch or gum, which in no way would have contributed to the flavour of the product. This can be entirely psychological. The line between psychological and physiological reactions is not always easy to draw. Our taste buds respond in a complex fashion, which is not yet fully understood.

Flavour can be measured either by using sophisticated instruments such as gas chromatography that measures specific volatile compounds responsible for that particular flavour or through sensory methods. Acidity can be measured by titrating with alkali or using a pH meter. Although, when it comes to consumer quality acceptance, there is still no substitute for the measurements made by having people taste products.

Check your Progress Exercise 1

1. Fill in the blanks:

(i) Some of the factors that we consider while selecting food products are-------------, --------------, -----------------, -------------------, and ----------------------- .

(ii) A degree of excellence and includes things such as taste, appearance and nutritional content is referred to as -------------------.

(iii) When sensory organs are used to assess the quality of a food product, the evaluation is said to be------------------------or----------------------or--------------------

(iv) The quality of a food can be categorized into --------------------, --------------------- and ---------------------- .

(v) One of the major determinants of liking or disliking of a food is --------------------.

2. Given below is a list of words that are used to describe sensory characteristics of foods. Classify them according to the odour, taste, appearance and texture properties.

a) Zesty --------------------
b) Gritty --------------------
c) Cuboid--------------------
d) Acrid --------------------
e) Stodgy --------------------
f) Rich --------------------
g) Floral --------------------
h) Fizzy --------------------
i) Clammy------------------
j) Bubbly-------------------

With the basic understanding about quality attributes of food, we will next review few of these attributes in more detail starting with 'taste'- a basic characteristic of foods.

8.3 GUSTATION - THE SENSE OF TASTE

The word 'taste' means not only a sensory response to the soluble materials in the mouth but also aesthetic appreciation. It has been noted many times that among human senses, taste has been called the "poor relation". Perhaps, it is because taste contributes so few important qualities to the sum of human experience, when compared to vision or audition. From the view point of the food processor and food scientist, the sense of taste commands interest because of its role in food recognition, selection and acceptance, in addition to its pleasure giving function.

We have described the organs involved in taste perception in the Course on Applied Physiology, Unit 10. It would be a good idea to look up the unit now. This will help you understand the role of taste in food recognition, selection and acceptance.

You already know that taste is sensed by taste buds located on the tongue. Taste sensations which taste buds register are categorized as - sweet, sour, salt and bitter. Sweet and salty tastes are sensed more intensely on the tip of the tongue. Sour and bitter more intensely on the hard palate. Are you aware of the chemicals responsible for the four basic tastes and what are the factors affecting taste quality? The next sub-section introduces you to these concepts.

8.3.1 Chemicals Responsible for the Four Basic Tastes i.e. Sweet, Salt, Sour and Bitter

The chemicals responsible for imparting the sweetness, classic salt taste and bitter and sour taste are summarized herewith.

A. Sweet Taste

Sweetness is one of the most important taste sensations for humans and for many animal species as well.

Substances which elicit 'sweet' sensation are primarily the organic compounds like sugars - mono and disaccharides, glucose, fructose, sucrose, various alcohols mainly ethanol, sorbitol, glycerol, non-nutritive sweetners such as saccharine, cyclamate, aspartame.

Among them, sugars are the main sources of sweetness in foods. But not all sugars are equally sweet. Fructose gives the most intensely sweet sensation followed by sucrose, glucose, maltose, galactose and lactose respectively. Alongwith imparting sweetness to foods, you have learnt earlier about the other functional properties of sucrose in foods that make it useful as a bulking agent, texture modifier, mouthfeel modifier and a preservative. Sucrose additionally offers an important energy source for many food fermentations.

The threshold value for sucrose is 0.342%, glucose is 1.442% and saccharine is 0.00047%. What do we mean by threshold? *The concentration required for identification is known as threshold for that particular substance*.

Next let us learn about the salty taste.

B. Salty taste

Various ions both *cations* and *anions* are responsible for the salty taste. These include: K (Potassium), Na (Sodium), Li (Lithium), Cl, Br (Bromine), I (Iodine), F(Fluorine), SO_4 (Sulphate), NO_3 (Nitrate). As you move from Li to NO_3, the molecular weight increases and saltiness decreases. Threshold values for some salts are given herewith:

NaCl (Sodium chloride)	0.175%
LiCl (Lithium Chloride)	0.016%
NaBr (Sodium Bromide)	0.247%
NaI (Sodium Iodide)	0.42%

'Salty' taste is due to ions of salts. Classic salty taste is represented by Sodium Chloride (NaCl).

C. Bitter Taste

Bitterness is an inherent property of a substance. It is due to substances such as alkaloids present in food. For example, tannins present in tea, coffee, fruits and vegetables. Tannins are desirable in tea and coffee to some extent but not in fruits and vegetables. Apple juice, if left outside, gives a bitter taste due to the tannins present in it. Some electrolytes are also bitter e.g. magnesium (Mg), ammonia (NH_3) and other nitro compounds. More the number of nitro compounds, higher will be the bitterness perceived. Various amides are also bitter for example, benzamide and glycosides. Quinine, (found in grapes and citrus fruits) naringin (grape fruit), lemonin (citrus fruits), thromine, bromide, caffeine (coffee), Mg, NH_4, Ca, picric acid and various nitro groups are the compounds responsible for the bitter taste. Certain phenyl groups are also responsible for bitter taste, urea also gives bitter taste.

Debittering of these citrus fruits can be done by using advanced techniques such as super critical fluid extraction. What is this technique? CO_2 at super critical pressure and temperature causes extraction of these bitter components from these substances.

D. Sour Taste

Sour taste is usually due to the presence of acids such as acetic acid, citric acid, benzoic acid. Upon dissociation, the acids give H ions which impart acidity. More the H ion concentration higher is the acidity and more is the intensity of sourness. Fruits and vegetables are sour due to the acids present in them for example, tartaric acid in grapes and citric acid in lemon. Acids may be strong or weak depending upon their dissociation ability. Stronger the acid more will be the dissociation and higher will be the acidity, which imparts sourness to a particular substance. Of the two acids, HCl and acetic acid (CH_3COOH), acetic acid is more sour than HCl inspite of the fact that HCl is stronger. This indicates that there are other factors also along with the dissociation governing the intensity of sourness. All these factors influence the *reaction time* which is defined as the *time interval between tasting of a substance and identification of the taste by the brain.* The solution is first tasted, the impulse is transmitted to the brain and then identification takes place or in other words, reaction time interval between initial stimulation of the receptors and the final response.

The reaction time to perceive the acidic taste is indirectly proportional to the concentration of the acid. More the concentration, lesser is the time required. Individual variations are there in perception due to difference in the pH of the saliva. Low pH saliva will give a better perception of sour taste.

After understanding the four tastes, let us look at the factors affecting taste quality.

8.3.2 Factors Affecting Taste Quality

You may have experienced that the four primary tastes i.e., sweet, sour, salty and bitter are not sensed with an equal ease. There are many factors which influence the sensitivity. What are these factors? Read and find out.

1. *Concentration* **-** There is a specific range at which the tasteful substances should be used. The concentration required for identification is known as the *threshold* for that particular substance. Within this range, the perception of taste increases with an increase in concentration. Below and above this concentration, taste is not adequately perceived.

Threshold may be defined in terms of absolute threshold or recognition/detection threshold or terminal threshold. Absolute threshold is the *minimum detectable concentration*. It is not a sharply defined concentration. It is the *stimulus magnitude at which the subject can identify different tastes*. Recognition/Detection Threshold, on the other hand, is *the concentration at which the subject can identify a specific taste*. It is always higher than absolute threshold. *Terminal threshold* is the maximum concentration beyond which taste is not perceived or a change in sensation is not perceived, how much high the concentration is.

Range starts from recognition threshold to terminal threshold. For sweet taste, this range is very wide, for salty and sour the range is narrow, and is very narrow for the bitter taste. Most acceptable concentration for different tastes is included herewith:

For sweet: 7-9%, in all desserts and beverages. A high concentration is used in jams and jellies, where it acts as a preservative.

For sour – 0.28%

For salty – eg., NaCl in cheese and butter – 2%

For bitter- 0.0002%

2. *Taste interactions***-** Foods contain a mixture of substances which elicit all four sensations. Modification of one sensation takes place in the presence of other. For example, addition of sugar to tea extract or lemon to tea extract i.e. bitterness is suppressed by sweet or sour.

Out of the two sensations, the stronger one may repress the effect of other. For example, salt in sub-threshold concentration reduces the tartness of acid, salt is added to sweet fruits to modify the sweet taste or to make it more acceptable. Sugar or lemon added to the tea, which otherwise is very bitter, modifies the bitter taste.

3. *Adaptation* – A low concentration solution will not give any sensation after tasting a higher concentration solution due to the adaption of the tongue for higher concentration. For example, normal water will taste flat because our tongue is adapted to this type of water but when we take hard water, it appears salty. Mineral water/ground water containing many minerals and ions gives a salty taste. Distilled water containing no ions tastes slightly sweet. Tea taken after sugar appears flat i.e. does not gives a bitter perception.
4. *Time*- Time is another factor which affects sensation. Salt on tongue is sensed in a fraction of a second; whereas, bitter things may require longer time, say one full second. Once perceived, it however, keeps on lingering. Table 8.2 gives the reaction time for different tastes.

Table 8.2: Reaction time for different tastes

Tastes	Reaction Time in Seconds
Sweet	0.44
Salty	0.3
Sour	0.53
Bitter (Max)	1.08

From our discussion above, we hope you have gathered some insight into the role of taste in food acceptance and the factors which influence this attribute. To help you recapitulate what you have learnt so far, we have included some exercises to Check Your Progress Exercise 2. Answer them and check your responses with the answers given at the end of this unit.

Check Your Progress Exercise 2

1. Fill in the blanks:

(i) Taste is called as a poor relation as it contributes to -----------------------------------

(ii) Taste sensations can be categorized as -------------, --------------, ------------- and ------------------- .

(iii) ----------------------- are the substances that elicit sweet sensation.

(iv) The detection threshold for quinine is -------------------------------- .

2. Which are the areas where various taste sensations are perceived?

----

3. Explain the following terms:

(a) Threshold

(b) Reaction time

----

4. List the factors that affect the taste quality.

Next, we move on to the texture in foods.

8.4 TEXTURE IN FOODS

According to Matz (1962), texture can be defined as *the mingled experience derived from the sensation of skin in the mouth after ingestion of food or beverage*. What we sense as texture in foods, derives from the physical characteristics of these materials. **We generally concern ourselves with hardness of tough meat, softness of tender jellies,**

chewiness of steak, thickness of sauces, elasticity of bread, sticky surface of caramel, roughness of salt crystals etc. to realize how many characteristics provide textural stimuli in foods. In other words, *texture is a composite property involving many physical properties in a complex relationship* or in a more general way, *texture can be defined as a way in which various constituents and structural components are arranged and combined into a micro and macro structure and the external manifestation of the structure in terms of flow.* The formation texture influences:

(1) Consumer acceptability,

(2) Type of packaging, and

(3) Processing method (Power required).

We learnt earlier that texture is observed in terms of tactile sensations i.e. fingerfeel and mouthfeel. *Finger feel* is sensed before ingestion, by pressing and touching, e.g. to detect the freshness or staleness of bread by handfeel. On the other hand, once you ingest the food the mixed feeling derived mainly due to the activation of palate and teeth, is the *mouthfeel*. During chewing, various kinds of forces are applied which tell us about the texture of the food. The forces are compression, cutting, tensile strength and shearing. These same kinds of forces are imitated in the objective evaluation of textural properties. *The term 'mouthfeel' can therefore be defined as the mingled experience arising from the sensation of the skin and the mouth during and after ingestion.*

You may be wondering why a study of the food texture is important. The study of food texture is important for three reasons:

1. To evaluate the resistance of product against mechanical action such as in mechanical harvesting of fruits and vegetables,
2. To determine the flow properties of a product (what is referred to as rheology) during processing, handling and storage, and
3. To establish the mechanical behaviour of food when consumed.

Next, how do we measure food texture? Food texture can be evaluated by mechanical test or instrumental methods. This is called as *objective evaluation*. When we use the human sensory organs as analytical tools, we call it the sensory or subjective evaluation. For the purpose of measurement, however, classification in terms of physical properties has been proposed by Szczesmiac in 1963. This system groups the characteristics as mechanical (hardness, cohesiveness, viscosity, elasticity, adhesiveness), geometrical (particle size, shape and orientation) and others (moisture content, fat content) as highlighted in Table 8.3.

Table 8.3: Different Textural Parameters and their popular classification (Szczezmiac Classification (1963)

S. No	Primary Parameters	Secondary	Popular Nomenclature
1. *Mechanical Characteristics*			
a.	Hardness		Softness Firm → hard
b.	Cohesiveness	Brittleness Chewiness Gumminess	Crumbly – Crunchy – Brittle Tender – Chewy – Tough Mealy – Pasty – Gummy
c.	Viscosity		Thin → Viscous
d.	Elasticity		Plastic → Elasticity
e.	Adhesiveness		Sticky → Tacky – Gooye
2. *Geometrical Characteristics*			
a.	Particle size and shape		Gritty Grainy Coarse
b.	Particle shape and orientation		Fibrous – Cellular – Crystalline
3. *Other Characteristics*			
a.	Moisture Content		Dry-Moist-Wet-Watery
b.	Fat content	Oiliness	Oily Greasy

Hardness, cohesiveness, viscosity, elasticity and adhesiveness are the mechanical characteristics. What do these characteristics stand for? These characteristics are described in physical terms herewith for your convenience.

Hardness: It is defined as *the force necessary to affect a given deformation*. When judged by human senses, it is the force required to penetrate a food with molar teeth. Solids and some semi-solids have this property. For example, Cream cheese is low in hardness and raw candy is very hard.

Cohesiveness: It derives from the *strength of internal bonds holding the body of the substance together*. Cohesiveness, being the primary characteristic includes - brittleness, chewiness and gumminess – as the secondary characteristics. What are these characteristics? Let us know. *Brittleness* is judged by the taster as the ease with which the food can be cracked, then shattered or crumbled. *Chewiness* can be defined as the resistance of a product to compression and shearing action of teeth or the energy needed to masticate a solid food and *gumminess* can be understood to include the resistance offered by food when teeth/tongue are withdrawn after first penetrating the food i.e. the energy required to disintegrate a semi-solid food prior to swallowing.

Viscosity: It is measured as *the rate of flow per unit force*. The resistance of liquids to flowing is readily observed and is usually conveniently measured. For example, in the mouth, it is sensed as 'body' or thickness by small variation of resistance against the sensitive touch receptors of lips, cheeks, palate and tongue.

Elasticity: It is defined as *the rate at which a deformed material goes back to its original shape*. Elasticity is difficult to measure independently of other parameters. It is a part of chewiness.

Adhesiveness: It is measured as the work necessary to overcome the attractive forces between surfaces of material and surfaces that contact it. In eating, this property is sensed between food surfaces and mouth/throat tissues. For example, oil allows little adhesion, while peanut butter much.

All these textural characteristics discussed above are the working basis for food researchers, quality control experts and engineers busy in developing instruments to measure texture. In this section, we will study about objective evaluation of food texture. How is the food texture measured? What are the different methods and instruments used for measuring texture of different foods?

8.4.1 Objective Measurement and Evaluation of Food Texture

Kinesthetic characteristics deal with the sense of feel, just like the characteristics of appearance deal with the sense of sight.

Objective methods of textures measurement involve simulating and measuring the sensations which the consumer experiences through the sense of feel with the fingers and more precisely in the mouth.

Many of these instruments used to measure texture, involve measurement of resistance to the force applied which is measured in terms of grams/kilograms force. This force may be applied in a number of ways or through a combination of two or more of the methods highlighted herewith. Basically four types of forces are encountered, which include:

Four Types of basic forces

1. *Compression:* This refers to *the squeezing of the test material so that it still remains as a single undivided unit but may occupy less volume*. Figure 8.1 illustrates this type of squeezing. For e.g. finger test and pressure test to measure the juiciness, firmness etc.

Figure 8.1: Compression

2. *Cutting* – This occurs when the force is applied in such a way that the test unit is divided so that the portions in the original position in relation to each other, as you can see from the figure 8.2.

Figure 8.2: Cutting

3. Shearing – This results from *the application of force where the test material is separated to two or more parts as shown in the figure 8.3, with one part sliding beyond the other part* e.g. separating dough into two parts.

Figure 8.3: Shearing

4. Tensile strength – This is the application of force away from the material rather than towards the material, when a force is applied to pull the test material apart. This is illustrated in the figure 8.4. There may be one force or combination of two forces, such as shear pressure.

Shear Pressure – Both shearing and compression. The food is first compressed, then sheared for example tenderometer, chewing action of teeth etc.

Figure 8.4: Tensile Strength

Earlier we learnt that the textural properties include mechanical properties of hardness, cohesiveness, adhesiveness, chewiness, crispness, gumminess, viscosity and elasticity etc. A number of instruments are available to evaluate the texture of various foods. A brief discussion on these instruments follow.

Considering the various textural characteristics of food, you will find that different instruments are used to measure their different mechanical characteristics. A few examples are: (i) the tenderness of meat is tested by measurement of structure of meat with a *penetrometer*. This measurement gives an idea of how easy or difficult it is for the teeth to bite into a piece of meat. Another device used to measure tenderness is *Warner Braztler Shear*. This measures the force needed to cut the meat in simple shear usually across the fibres and estimate the force needed to chew the meat.

(ii) The texture of fruits and vegetables can be measured as follows:

a) *Punctured testing* is used to evaluate firmness of fruits. It measures the amount of force required to penetrate the sample to a specific depth.

b) A *shear press* is used to study tenderness of fruits and vegetables. This consists of a rectangular box with evenly spaced slits at bottom. A series of blades is moved through a sample of food. As the blades move, food is compressed, sheared and extruded through the openings in box.

(iii) The texture of doughs and batters determine the quality of finished product. Consistency of batters is determined by *"Line-spread apparatus"*, which indicates the nature of dispersion of incorporated air. Consistency and stability of doughs are measured with a *"farinograph*", which measures the force required to turn mixer blade at a constant speed during mixing of the dough. A *"mixograph*" also gives information similar to farinographs.

(iv) Texture of baked products - pastries, cookies and crackers is determined by *"shortometer*". It measures the force required to break the products. A "*compressimeter"* is used to evaluate the firmness of breadcrumbs or softness of baked products. The force requires to break through a sample of baked product can be measured using "Warner-Braztler Shear".

Textures, as perceived by human beings, is a composite of characteristics to arrive at a textural profile. Different new instruments have been developed to evaluate more than one characteristic constituting texture of a food. One such multiple measuring devices – Instron – texture measuring system, can measure many properties at the same time e.g.

firmness, grittiness, case hardening etc. by the use of force and time curves. In this, force and time are varied simultaneously. For surface hardening a steep rise is obtained in the curve. For a less firm product, there will be a gradual rise. For gritty particles, a number of sharp peaks depths are observed.

Some characteristics of food depend on *rheological properties.* What are these properties? What do we mean by rheology of food? The next section presents a discussion on food rheology.

8.4.2 Rheology of Foods

Rheology is *the study of stress and strain* or in other words*, it is the study of flow and deformation of materials, both liquids and solids, under stress and strain conditions*. Primarily, rheology deals with three aspects –Elasticity, Plasticity and Viscosity.

The flow characteristics of a food are actually quite complex. For example, if a bread dough is stretched, but not too far, it will spring back; to the extent that it does, the dough is elastic. Elasticity is a characteristic of importance in baked products too. Such as crumb of bread and cake, especially so when they are fresh.

Elastic deformation is reversible but plastic is not. A material that exhibits plastic flow resists changing position until a minimum force is applied. This is a desirable characteristic in cake frosting. A soft frosting is desired, but it should stay in place but not flow down the sides of the cake.

Solids do not flow; however, some solids can be deformed by force and recover when the force is removed. This is elasticity and gels like those of pectin, gelatin and starch baked custard etc. are examples of elastic solids. There a number of objectives tests to determine the firmness of gels. A material that is plastic resists flow until a force is applied but unlike elastic flow, plastic flow is irreversible.

What is *viscosity*? Viscosity is resistance to flow of a liquid. It is a measure of the resistance of a fluid to deformation under shear stress. It is commonly perceived as "thickness", or resistance to pouring. Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction. Thus, water is "thin", having a low viscosity, while vegetable oil is "thick" having a high viscosity. While studying about viscosity you will come across terms such as newtonian fluid and non-newtonian fluids. What do we mean by this? A Newtonian fluid is one in which the viscosity does not depend on the shear rate—no matter what shear is applied, the viscosity stays the same. Examples of newtonian liquids are mineral oil, water and molasses. In many applications, however, this is not the case and, as the fluid is sheared at greater rates, the viscosity will change. These types of liquids are known as non-newtonian and there are many classifications. Examples are toothpaste and whipped cream.

Various methods for textural or rheological measurement are used. We will not go into the details of these methods here in this unit, but certainly highlight a few method used to measure rheological parameters.

The first type of rheological model highlighted here is Dash pot model.

1. *Dash Pot Model:* This method establishes relation between the pressure gradient and the volume rate of flow. Here, the piston measurement is used to measure the consistency of the product present in the cylinder. If the load required is more, consistency is thick. It consists of a piston sliding in the cylinder filled with oil as shown in the figure 8.5. Here, the load is connected with piston, as you can see from the figure 8.5, which provides the force for piston movement. If the viscosity is high, more load is required to obtain a constant movement. Oil can be replaced by the food material for which the measurements are to be taken. The initial period of no deformation is there. The piston starts moving only after a critical load is applied. After sometime, the deformation remains constant. This model can be used only for fluid test products.

Figure 8.5: Dash Pot Model

2. Spring Model

The spring model depicts elasticity. A force is applied in terms of load onto the spring as illustrated in the figure 8.6. When the force is applied, deformation is produced which will remain constant for sometime and the spring will immediately regain its shape after removal of a load.

Figure 8.6: Spring Model

This is ideal for the elastic materials. In case of food, the spring is replaced with food material or elastic food, for which the deformation is to be measured. For example, extensiometer for measuring the dough elasticity and extensibility.

3. *Spring clip model:* The spring clip model differs from the spring model in a way that the force applied is comparatively slower. This also depicts elasticity or plasticity of a material. The force is controlled by pulley arrangement as shown in the figure 8.7. It is used for measuring the breaking strength of dough. Initially, for sometime, it resists the flow. Once started with the deformation and after completion of deformation, it becomes still.

Figure 8.7: Spring Clip Model

4. Shear Pin Model: In this type, a shearing force is applied using a pin to shear the food product, as illustrated in the figure 8.8. We are rupturing the element of the food product by using pin.

Figure 8.8: Shear Pin Model

Check Your Progress Exercise 3

1. Define the following terms:

(i) Texture

(ii) Mouthfeel

(iii) Hardness

(iv) Cohesiveness

(v) Elasticity

(vi) Adhesiveness

(vii) Chewiness

(viii) Rheology

----

2. Fill in the blanks:

(i) Objective methods of texture measurement involve---------------- and --------------------- sensations.

(ii) The four basic types of forces encountered while evaluating food texture are ----------------------, ---------------------, --------------------- and --------------------- .

(iii) -------------------------------- is an instrument used to evaluate multiple characteristics of food texture.

(iv) Rheological parameters can be measured by ----------------------, --- and ----------------------- .

(v) Few examples of elastic solids are --- .

3. Name a few instruments that are used to measure the texture of:

(i) Meat

(ii) Fruits and Vegetables

(iii) Doughs and Batters

(iv) Baked products

8.5 COLOUR

Colour is an important quality attribute in food although they do not necessarily influence their nutritional, flavour or functional quality. Consumer preferences are strongly influenced by the colour of the food. Colour is defined as *the characteristic of light that is measured in terms of intensity and wavelength*. Why is colour an important characteristic of food? What are its functions? How can we measure colour in foods? These are a few aspects covered in this section. We begin by first understanding the functions of colour in foods.

8.5.1 Functions of Colour in Foods

Earlier, in section 9.2 we very briefly introduced you to the colour properties of food and its role in food. Let us now look at the different functions of colour in details, which are enumerated herewith:

1. The maturity of many fruits and vegetables is closely associated with colour development or changes in colour. Colour is also indicative of the freshness of the product. Changes in colour take place on storage that may lead to reduced or increased consumer acceptance e.g. in tomatoes- green- yellow- red. So *colour acts as a ripening index in fruits and vegetables.*
2. *Composition Aspects*- Colour indicates the composition of the food. For example, in egg yolk, the intensity of yellow colour tells us about the pigment content.
3. *Grades* are assigned to the food products on the basis of their colour. For example, tomatoes are graded according to their size and colour. Different prices are allocated for different grades. This is important for canning industry where they assign different grades to the canned tomatoes.
4. The *end point determination* during food processing is also done on the basis of the colour of the final product. For example, golden brown colour of the fried products.
5. Distinct colours are associated with different flavours e.g. pink colour to strawberry flavour, yellow to mango flavour and orange to orange flavour etc.
6. It has been seen that the flavour scores of an inferior grade (poor quality) juice can be improved by colouring it to resemble the juice of better quality. So *colour serves as a standard of good quality*. Also, the flavour identification becomes difficult if the products are coloured deceptively. For example, green colour for an orange juice. Also people describe white wine as less sweet in taste in comparison to the red wine even though the sugar concentration has

been kept constant. Example, orange juice which had a yellow colour has been found to be less acceptable in comparison to bright orange colour juice.

Well then, colour, as is evident from the discussion above plays a crucial role in food acceptability. It contributes immeasurably to ones aesthetic appreciation for food in addition to being associated with other attributes. A number of instruments are used for colour measurements. The next sub-section presents a review on these instruments.

8.5.2 Measurement of Colour in Foods

A number of instruments are used for colour measurements in food. In this section we shall acquaint you to some of the simple methods/instruments used to measure colour in foods. These are highlighted herewith:

a) A simple method is to match the colour of a food with coloured chips or glass and give them name accordingly.

b) Disc Colourimetry, in which different coloured discs are spun on a stage, so that the colours merge into one colour. The test sample is placed adjacent to the spinning disc and the colours are matched.

c) Tintometers are simple instruments used to determine the colour and its depth in foods for a more reliable measurement of colour.

d) Spectrophotometers are also used to measure colour. In the case of clear and transparent solutions, spectrophotometric measurements give quantitative results. For the foods that are opaque in nature, "reflectance spectrophotometry" is used. In the Reflectance Spectrophotometery, colour is measured in terms of amount of light reflected from the surface of the object at each wavelength in the range of 380-700 nm.

e) Tri – Stimulus Colourimetry, in which the colour is specified by three attributes - dominant wavelength, brightness and purity- hence referred to as tristimulus system. These three refer to the actual colour, luminosity and strength of the colour respectively.

Other than the measurement of colour, analysis of colour in food is also important. You may recall reading about the three different classes of colours – natural, synthetic and natural identical, earlier. How can we analyse or check whether the colour present in food, particularly the synthetic one, is permitted or not? There are different ways of colour analysis. The next sub-section throws light on this analysis.

8.5.3 Qualitative and Quantitative Analysis of Colour

Primarily, two types of analysis are carried out for food colours - qualitative and quantitative.

The qualitative analysis is carried out to check whether the dye present in food as a colourant is permitted or not. This is done with the help of various separation techniques Gas Liquid Chromatography (GLC), Thin Layer Chromatography (TLC), paper chromatography and spectrophotometry.

The colour from the food product is extracted and subjected to one of these techniques for identification of colour. In case of paper chromatography and TLC, reference values of the extracted colours is compared with that of standard and in case of GLC, retention time values are compared. Retention time is *the time taken by the component to elute from the column.*

Quantitative analysis, on the other hand, is done to check whether the amount present is within the prescribed limits or not. In case of GLC area of the peak obtained is directly proportional to the amount of the component present. In case of TLC the spotted portion is scrapped from the plate and dissolved in a suitable solvent filtered and the colour intensity is measured using spectrophotometer. If the artificial colours used are preset beyond the prescribed limit they might prove to be toxic to the human health. All these determinations are done for synthetic colours only.

With qualitative and quantitative analysis of colours in foods, we come to an end of our study on the properties of foods.

Check Your Progress Exercise 4

1. Give the functions of colours in foods.

----

2. Define the following terms:

(i) Colour

(ii) Retention time

----

3. List a few methods to measure colour in foods.

8.6 LET US SUM UP

In this unit, you studied about various properties of foods, under which the quality attributes of foods were introduced to you in terms of food quality and its categories as appearance, texture and flavour factors. The sensory or subjective evaluation of foods was also described.

A detailed discussion on the sensory characteristics of foods was done, that included gustation, texture and colour. In this, you learnt about the techniques of measurement, analysis and evaluation of these characteristics.

8.7 GLOSSARY

Absolute threshold : The minimum detectable concentration; stimulus magnitude at which the subject an identify different tastes.

Adhesiveness : The work necessary to overcome the attractive forces between surfaces of material and surfaces that contact it.

Bitterness : A sensation of a peculiar, acid, biting taste.

Brittleness : The ease with which a food can be cracked.

Chewiness : The resistance of a product to compression and shearing action of teeth.

Cohesiveness : The strength of internal bonds holding the body of the substance together.

Colour : The characteristic of light that is measured in terms of intensity and wavelength.

Compression : The squeezing of the test material so that it still remains as an undivided unit but may occupy less volume.

Disc Colourimetry : A technique by which an unknown colour is evaluated in terms of standard colours; used in chemistry and physics; may be visual, photoelectric, or indirect by means of spectrophotometry.

Dissociation : The process that may occur when a chemical compound breaks up into simpler constituents as a result of an action of a solvent or a change in physical condition, as in pressure or temperature, causes a molecule to split into simpler groups of atoms, single atoms, or ions.

Elasticity : The rate at which a deformed material goes back to its original shape.

Emulsifying agents : An agent used to bind oil soluble and water soluble ingredients.

Flavour : A combination of taste and odour or smell or aroma.

Gas chromatography : The separation of a mixture of compounds into separate components, which then can be analyzed by a mass spectrometer to yield detailed empirical molecular information regarding chemistry of sample.

Gas Liquid

Chromatography : The substance is held stationary by an inert solid coated with an inert liquid which is not likely to evaporate, while a gas flows past it bringing out the components one at a time.

Grades : A set of things all falling in the same specified limits; a class.

Gumminess : The energy required to disintegrate a semi-solid food prior to swallowing.

Gustation : An act of tasting.

Luminosity : The quality of being luminous; emitting or reflecting light.

Mouthfeel : The mingled experience desiring from the sensation of the skin and the mouth during and after ingestion.

Objective Evaluation : Evaluation by mechanical test or instrumental methods.

Odour : The sensation that results when olfactory receptors in the nose are stimulated by particular chemicals in a gaseous form.

pH meter : A device used to measure hydrogen ion concentration or pH.

Quality : A degree of excellence and includes such things as taste, appearance and nutritional content. It is the composite of characteristics that have significance and which help in making the product acceptable.

Reaction time : The time interval between tasting of a substance and identification of the taste by the brain.

Recognition/Detection

Rheology : Study of stress and strain; the study of flow and deformation of materials, both liquids and solids under stress and strain conditions.

Sensory evaluation : When the quality of a food product is assessed by means of human sensory organs.

Shearing : The application of force where the test material is separated to two or more parts with one part sliding beyond the other part.

Spectrophotometer : An instrument for measuring or comparing the intensities of the colours of the spectrum.

Tensile strength : The application of force away from the material rather than towards the material.

Terminal Threshold : The maximum concentration beyond which taste or a change in sensation is not perceived.

Texture : A composite properly involving many physical properties in a complex relationship.

Threshold : The concentration required for identification.

Threshold : The concentration at which the subject can identify a specific taste. It is always higher than absolute threshold.

Tintometer : A measuring instrument used in colorimetric analysis to determine the quantity of a substance from the colour it yields with specific reagents.

Viscosity : The rate of flow per unit force.

Wavelength : The distance between successive peaks or nodes of a wave.

8.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

(i) colour, wholesomeness, gloss, degree of ripeness, smell, taste and texture

(ii) quality

(iii) sensory; subjective; organoleptic

(iv) appearance; texture and flavour

(v) texture

2.

a) taste

b) texture

c) appearance

d) odour

e) texture

f) taste

g) odour

h) appearance

i) texture

j) texture

Check Your Progress Exercise 2

1.

i) few important qualities.

ii) Sweet, sour, salty and bitter

iii) Organic compounds

iv) 10 ppm

2. The areas where various taste sensations are perceived are:

- Sweet taste: more on the tongue than on hard palate
- Bitter taste: hard palate
- Salty taste: tip of the tongue
- Sour taste: hard palate

3.

a) Threshold is the concentration required for identification

b) Reaction time is the time interval between tasting of a substance and identification of the taste by the brain.

4.

Concentration, taste interactions, Adaptations and time.

Check Your Progress Exercise 3

1.

(i) Texture is a composite property involving many physical properties in a complex relationship

(ii) The mingled experience arising from the sensation of the skin and the mouth during and after ingestion is referred to as mouthfeel.

(iii) Hardness is the force necessary to affect a given deformation.

(iv) Cohesiveness is the strength of internal bonds holding the body of the substance together.

(v) The rate at which a deformed material goes back to its original shape is referred to as elasticity.

(vi) Adhesiveness is the work necessary to overcome the attractive forces between surfaces of material and surfaces that contact it.

(vii) Chewiness is the resistance of a product to compression and shearing action of teeth, or the energy needed to masticate a solid food.

(viii) Rheology is the study of flow and deformation of materials, both liquids and solids, under stress and strain conditions.

2.

(i) Stimulating and measuring the sensations

(ii) Compression, cutting, shearing, tensile strength

(iii) Instron – texture measuring system

(iv) Dash pot model, spring model, spring clip model and shear pin model

(v) Gels of pectin, gelatin and starch baked custard

3.

(i) Meat - penetrometer; Warner Braztler Shear

(ii) Fruits and vegetables - punctured testing; shear press

(iii) Doughs and batters - line-spread apparatus; Farinograph; mixograph

(iv) Baked products - Shortometer; Compressimeter; Instron – texture measuring system

Check Your Progress Exercise 4

1. The functions of colour in foods are: as a ripening index, indicator of composition of food, allocation of different grades, determining the end point during processing, association with different flavours and indicator of standard of good quality.

2.

(i) Colour is the characteristic of light that is measured in terms of intensity and wavelength

(ii) Retention time is the time taken by the component to elute from the column.

3. Matching the colour of a food with coloured chips / glass, Disc colourimetry, Tintometers, Spectrophotometers and Tri-stimulus colourimetry.

UNIT 9: CHEMICAL, PHYSICAL AND NUTRITIONAL ALTERATIONS OCCURING IN FOODS DURING PROCESSING AND STORAGE

Structure

9.1 INTRODUCTION

In the first block of this course, we have talked about the major constituents, that is, carbohydrates, proteins, lipids and their physico-chemical characteristics. We have also acquired detailed knowledge about vitamins, minerals, enzymes, pigments and flavours, where we had primarily focused on the structure, occurrence of these in the food in their natural form and their application in the food industry. As you are aware that food is a perishable commodity it undergoes various physical, chemical and microbial changes; that might be undesirable. Hence, to prevent such changes and to ensure its future use and availability all round the year, it must be processed and stored using scientific techniques. We will learn about food processing in Units 10, 11 and 12 of this course. Now in this unit, we shall direct our attention to the alterations occurring in the constituents of food during processing and storage. The knowledge gained regarding the chemical composition and physico-chemical properties of food in the earlier units would be useful here for interpreting the changes, which occur during processing and storage.

Objectives

After going through this unit, you will be able to:

- understand the need of food processing
- identify specific changes in a particular food due to various types of processing
- discriminate between favourable and unfavourable reactions during processing and storage in different groups of food and
- have an idea and think about optimization of process parameters to regulate chemical, physical and nutritional alternations according to the need

---

9.2 FOOD PROCESSING IN PERSPECTIVE

In the present scenario, food processing is very essential in order to achieve food security and in providing safe food to the people.

Food preservation, as you are aware, is *the process in which the perishable food materials are given a suitable physical or chemical treatment to prevent their wastage, spoilage and to retain their nutritive value for long periods*. Food processing can result in several advantages, some of which are substantial. These include:

- increased shelf-life
- decreased hazards from microbial pathogen
- decreased spoilage (microbial, enzymatic)
- inactivation of anti-nutritional factors
- ensured round the year availability of seasonal foods
- perishable foods can be transported to far-off distances from the site of production
- increased availability of convenience (e.g. Ready-to-serve beverages, Instant mixes) foods and

- increased variety of foods, some with enhanced sensory properties and nutritional attributes.

The above mentioned points highlight the importance of food processing. While processing food, you may have realized that many desirable changes occur, which include development of pleasing colours and flavors, improvement of texture and improvement of the functionality of food or ingredients. However, a number of undesirable changes may also occur during food processing which are generally product and process-specific like, damage to colour and flavour, damage to the nutritional properties and/or the development of toxic constituents etc.

Based upon the knowledge acquired about various changes (physical, chemical and nutritional), which may occur during food processing, it is necessary to optimize the process parameters so as to get a wholesome food product. In the subsequent sections in this unit, we shall look at various alterations occurring in different foods, during processing.

9.3 ALTERATIONS OCCURRING IN FRUITS AND VEGETABLES

You may already be aware that fruits and vegetables vary greatly in their chemical composition. However, some generalizations are possible. Fruits and vegetables have high water content, with a range from approximately 70 per cent for pears and bananas to 91 per cent for cabbage. The amount of protein and lipids in fruits and vegetables is usually very low, though both are good sources of vitamins particularly vitamins A and C. Part of the carbohydrate in fresh fruits and vegetables is present as cellulose and pectic substances in the cell wall. Starch is present in almost all fruits and vegetables, although it may decrease on ripening. Glucose, fructose and sucrose are widely distributed whose content vary considerably in various fruits and vegetables. Further, we have also seen that carotenoids, chlorophylls, anthoxanthins and anthocyanins are the chief pigments present in fruits and vegetables.

The detailed chemical changes that occur when fruits and vegetables are boiled in water or steamed, canned, dried or frozen, are still for the most part unknown. However, certain fruits and vegetables like apples, peaches, potato etc. turn brown when cut and exposed to air. This is a result of numerous enzymatic reactions that occur in fruit and vegetables on processing. These reactions may result in changes in the appearance, texture, flavour and colour of the fruits and vegetables. You may recall reading about these changes earlier in Unit 2.

Further, as a result of changes in the cell wall and intercellular structure, all fruits and vegetables undergo softening when cooked, no matter by what method. The changes occur in pectic substances, cellulose, starch and intercellular air. Cellulose, pectin and hemicellulose, as you have learnt earlier, are the major polysaccharide components in the cell wall of all plant foods. There has been a rapid progress in understanding the physical and chemical properties of polysaccharides in recent years. Studies on the role of cell wall components in food texture have been done, particularly on pectic substances. Alterations in pigments, formation of acids and release of low molecular weight sulfur compounds have been reported as the major changes during processing of fruits and vegetables. In a study, reactivation of a pectinesterase has been found in cucumber slices. When fresh cucumber slices were blanched for 3 minutes at 81^{o} C, enzyme activity could not be detected. However, when the blanched slices were stored in a pH 3.7, brine containing 0.6% acetic acid, 2.5% sodium chloride (NaCl), and 200 ppm sulphur dioxide (SO_2), about 20% of the activity present in the fresh tissue was regained during the first month of storage.

In processing fruits and vegetables, loss of carotenoids into cooking or canning water is very slight. However, carotenoids undergo oxidation when exposed to air, so that drying of fruits or vegetables which contain these pigments, a problem is sometimes encountered. For example, carrots and apricots show loss of pigment on drying. Anti-oxidants partially protect the pigment from deterioration, as it is reasoned that the degradation of the pigment might be associated with the oxidative changes in the fat.

Chlorophyll, the pigment responsible for giving bright green colour to the vegetables, is very unstable and undergoes changes in colour which are often considered to be undesirable. Have you ever noticed the colour change in spinach when boiled in water? Yes, the green colour of the spinach turns to olive green and then to brown when the leaves are cooked for long. Basically, chlorophyll changes to olive green colour and then to brown when the food is heated and the reaction is faster in acid solutions. When a vegetable becomes olive green on cooking, the chlorophyll gets converted to *pheophytin* (a derivative of chlorophyll). The reaction can be written schematically as indicated below. Hence, special care must be taken to produce food products from plant sources to retain a bright, attractive green colour.

$$C_{32}H_{30}ON_4Mg\begin{cases}COOCH_3\\COOC_{20}H_{37}\end{cases} + 2H^+ \longrightarrow C_{32}H_{30}ON_4H_2\begin{cases}COOCH_3\\COOC_{20}H_{31}\end{cases} + Mg^{++}$$

(Chlorophyll) (Pheophytin)

Dehydration is one of the ancient food processing techniques. *Dehydration means to completely remove water under controlled conditions, in such a way that minimal changes occur in the food item.* We will read about the technique later in unit 11. Here, let us focus on the changes occurring in fruits/vegetables during the process of dehydration. Vegetable dehydration reduces the natural water content below the level critical for the growth of microorganisms (12-15%), without being detrimental to important nutrients. Also, it is aimed at preserving flavour, aroma and appearance, and the ability to regain the original shape or appearance on reconstitution with water. However, the dehydration process is also accompanied by significant alterations. These include:

First, there is a concentration of major ingredients such as proteins, carbohydrates and minerals. This occurs along with some chemical changes. Fats undergo oxidative degradation and, although present in low amounts in vegetables, this oxidation often diminishes odor and flavour. Amino compounds and carbohydrates interact in a Maillard reaction (you would recall reading about the Maillard reaction in Unit 2), resulting in a darker colour and development of new aroma substances. Vitamin levels may also decrease sharply. The original volatile aroma and flavour compounds are lost to a great extent during processing depending upon the severity of the processing conditions.

Dried fruits are exceptionally rich in calories and they supply significant amounts of minerals. Of the vitamins found in fruits, β-Carotene and the vitamins of B-group are not significantly altered. Vitamin C is lost to a great extent. Sulfite treatment destroys vitamin B_1, however, fruit colour and vitamin C can be retained and stabilized.

Freezing is another ancient technique of food processing, which allows the transportation of perishable food items for long distances from production to consumption centres. *Freezing* refers to *freeze the available water of the food/food product and maintain it at -18^{o}C or below*. Freezing is mainly done for vegetables using conventional freezing techniques by indirect cold-transfer in plate or air freezers. We will learn more about freezing in Unit 11 later, but now we shall look at the changes/alterations occurring in fruits and vegetables, caused by freezing as a processing technique.

Freezing preserves vegetable and nutrients to a great extent. Vitamin A and β-Carotene are well preserved in spinach, peas and beans, or are moderately lost (asparagus) after proper blanching, freezing and deep freeze storage and even after thawing to room temperature. Losses in the vitamin B-group depend mostly on the conditions of the primary processing steps (washing, blanching). The other steps have no significant effect on B-vitamins. Leaching of vitamin C by water or steam is detrimental. It is generally preserved during freezing and thawing. Careful blanching and low temperature storage are critical for vitamin C preservation.

Uncontrolled freezing can result in the disruption of texture, denaturation of proteins and many other physical and chemical changes. Irreversible textural changes can occur in deep frozen vegetables. Typical symptoms are softening, ductile stickiness, or looseness or flaccidity (a flabby softness, as in beans, cucumbers carrots); build up of a sticky, ductile, gum-like structure (asparagus) or pasty, soggy structure (celery, kohlrabi) or hull hardening (peas).

Pickled vegetables are produced by spontaneous lactic acid fermentation. Fermentation improves the digestibility and wholesomeness of the product. The acidic pH of the medium stabilizes vitamin C. Pickled vegetables also develop a typical aroma, which is desirable.

Canning, which involves heat sterilization, is one of the most important processes in vegetable preservation. As compared to other foods, vegetable sterilization processes is carried out at towards a higher temperature and shorter time (HTST sterilization). In this way, the products retain a better quality in terms of texture, aroma and colour.

Check Your Progress Exercise 1

1. Fill in the blanks:

a) Fresh fruits contain carbohydrates as …………… and ……. …………… .

b) The component that is present in both fruits and vegetables and decreases on ripening is ………………… .

c) The chief pigments present in fruits and vegetables are chlorophylls, carotenoids, …………………and ………………… .

d) Cooking of fruits and vegetables results in changes in cellulose…………………, ……………… and ………………………… .

e) The enzyme present in cucumber that is activated during first month of storage is……………………

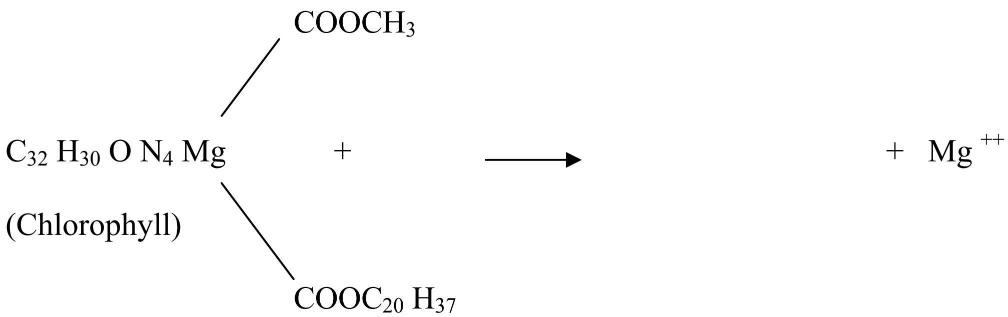
2. Mention the changes that occur in fruits and vegetables during the following processes.

a) Dehydration --
----

b) Freezing --

----

3. Complete the following reaction:



9.4 ALTERATIONS OCCURRING IN MILK AND MILK PRODUCTS

In the dairy industry, milk is commonly given heat treatment for a wide variety of purposes. Depending on the heating temperature, this procedure may cause several changes in milk, such as salt precipitation, due to the formation of insoluble complexes, protein denaturation and interactions among milk components. Heating milk at near boiling point causes a film or skin to form on the surface. This skin is mainly due to calcium caseinate but the other constituents in milk are also present in it.

Have you ever noticed what changes take place in milk if you heat it above its boiling point? Autoclaving milk, wherein temperature of around 121^{o}C is achieved, causes browning. The brown colour is due to the heat effecting an interaction between the casein (or amino acids) and the sugar. The process employed to heat milk also affects the changes in physico-chemical properties of milk. Research has shown that changes in certain physical and chemical properties of ultra-heated milk (95^{o}C to 145^{o}C) were much more severe when the milk was heated by indirect as compared to direct (steam injection) process. Increased browning and a greater amount of whey protein denaturation were particularly noticeable in ultra heated milk.

Apart from the above mentioned alterations, certain flavor changes also occur in milk, depending on the temperature and duration of heating. Heating milk to high temperatures causes a cooked flavor to appear. In the holding method of pasteurization (62^{o}C for 30 minutes) or the high-temperature short-time (HTST), 71^{o}C for 15 minutes methods - very little cooked flavor is noticed, but at higher temperatures or longer periods of heating, cooked flavor becomes more apparent. The flavor appears at 70^{o}C on momentary heating. This cooked flavor has been shown to be due to the production of *sulfhydryls* (compounds with a -SH group, found in many plant and animal enzymes) by high temperatures. Sulfhydryl compounds are readily oxidized and delay the oxidation of fat in milk or cream heated to high temperatures. Oxidized flavors in milk do not usually appear until the sulfhydryls are oxidized and the cooked flavor has disappeared.

Freezing the milk also alters its composition and properties to a great extent. Let us learn about these changes. As the milk freezes, it becomes very uneven in the composition of the frozen and other solids, while the liquid portion becomes concentrated with the milk solids, so much so that milk never freezes solid entirely. Freezing alters the physical condition of milk to the extent that it never returns to its original state. It causes the fat globules to lose their complete emulsion structure, to clump and become distorted and irregular in shape and size. The casein is also affected by freezing. It is partly broken from its existence in milk as calcium caseinate and gets precipitated as flakes. This condition, together with some free fat particles, gives the thawed-out milk an unnatural appearance. The flavor is also affected, being rather watery to the taste.

The caseinate micelles of milk, which are quite stable to heat, may be destabilized by freezing. On frozen storage of milk, the stability of the caseinate progressively decreases and may lead to complete coagulation.

Casein is an important example of protein, which can be boiled without apparent change in stability. The exceptional stability of casein makes it possible to boil, sterilize and concentrate milk, without coagulation.

Now we will have a look at the factors that have a bearing on viscosity. Low temperatures and aging induce clumping of the fat globules of milk, which increases the viscosity. Mechanical agitation of whole milk decreases the viscosity, because the fat globule clumps are partially broken up, while in the case of skim milk, it has no effect due to the presence of small amount of fats.

Homogenized milk will not be affected, as the fat globules are already broken up. Homogenization increases the viscosity of whole milk but slightly decreases that of skim milk. This process breaks up the fat globule into much smaller ones and thereby provides a larger surface area. A film of protein is adsorbed on the surface of the globules and this surface being much larger than in the non-homogenized milk, a much greater adsorption takes place, which causes a higher viscosity. Skim milk, some of the protein particles may be broken and therefore, the viscosity will be reduced.

Pasteurization temperatures slightly lowers the viscosity through breaking the clumps of fat globules, but when subjected to high heat, or high pressure, the viscosity is increased due to the denaturation of proteins.

9.5 ALTERATIONS OCCURRING IN MEAT AND POULTRY

Meat, as you already know, is rich in proteins and contains most of the essential amino acids. It is also rich in minerals such as copper and iron; vitamins such as A, B_1, B_2 and B_3. Its fat content varies from 5-40% with the type, breed, feed and age of the animal. Meats are rich in saturated fatty acids (SFA).A brief account of the effect of thermal treatment of meat products can be included. The intrinsic changes, which the muscles undergo in becoming meat, have not generally been considered, although it is increasingly recognized that their nature and extent may well determine the behavior of the meat.

It is important to point out that over-effective chilling of hot carcasses can lead to toughness. If the temperature of the meat (muscles) can be reduced to -10 to -15°C, whilst they are still in the early pre-rigor condition (pH about 6.0-6.4), there is a tendency for shortening and thereby, toughness on subsequent cooking. This phenomenon is referred to as *"cold-shortening"*. The tendency of cold shortening is greater when closer the temperature attained by the pre-rigor muscle is close to the freezing temperature.

The effect of irradiation on nutrients in meats and poultry has been the subject of considerable attention by researchers because they have been used as an argument against the approval and commercial application of this process. Most unreasonable aspect in this controversy is the consistent emphasis made on the detrimental effects of irradiation on food nutrients, including those in meat and poultry that has been reported to a large extent by the extrapolation of data gathered from the studies in which the selected, isolated nutrients were irradiated in model systems.

In terms of amino acid composition, high radiation doses such as those needed for sterilization (e.g. 25-27Kgy), do not change the content of cystine, methionine and tryptophan in beef, despite the fact that these amino acids are highly susceptible to damage by other processes. Data provided by Taub et. al. (1979) on the comparative effects of various processing techniques, including irradiation, on the amino acid content of beef are presented in Table No. 2.

Various studies have been conducted which indicate the effect of processing on vitamins especially, thiamine. In one study, which compared the effects of ionizing radiation and of conventional thermal processing on the thiamine content of enzyme–inactivated ground pork, concluded that sterilization by conventional thermal processing caused thiamine losses in pork were comparable to or greater than those caused by radiation sterilization.

Another study examined the combined effect of irradiation, storage and cooking on the thiamine content of minced pork. The pork was treated at 1Kgy while packaged in polyethylene bags at ambient temperature, followed by storage at 0^oC for 8 months, with or without heating for 10 minutes at 100^oC or 30 min at 200^oC before irradiation. The following results were obtained. Thiamine losses in unheated pork immediately after irradiation were 5%, whereas losses during refrigerated storage at 0^oC were no different from those in the non-irradiated samples. Heating pork at 100^oC for 10 minutes before irradiation had little additional effect on thiamine losses exhibited by unheated, irradiated samples.

Check Your Progress Exercise 2

1. State whether the following statements are True or False. Correct the false statements.

a) Low temperature and aging are the factors that lower the viscosity of milk.

----

b) Autoclaving milk has no effect on milk.

----

c) Heating milk to high temperatures gives it a cooked flavour.

----

d) An important milk protein, casein, on boiling remains stable.

----

e) The surface tension of milk is independent of fats and proteins.

----

f) High radiation doses have no effect on amino acid composition of meat.

----

g) Radiation sterilization leads to increased thiamin losses in pork than conventional thermal processing.

----

h) Thiamin losses were similar in refrigeration at 0^oC and in non-irradiated samples of minced pork.

----

2. Fill in the blanks:

a) The major component of the film formed on heated milk is -------------------- .

b) ……………… delay oxidation of fat in milk or cream heated to high temperature.

c) On frozen storage, the stability of caseinate progressively-------------------------- .

d) ………… increases surface tension of milk while ………………… decreases it.

e) Mechanical agitation greatly affects the viscosity of …….milk but has no effect on ……… milk.

3. Give reasons:

a) Browning caused in heated milk--
----

b) Cooked flavour in milk---
----

c) Freezing alters properties of milk--
----

4. What do you understand by the term 'cold shortening'?

………………………………………………………………………………………
………………………………………………………………………………………

9.6 ALTERATIONS OCCURRING IN FISH

The skeletal muscle of fish consists of short fibers arranged between sheets of connective tissue. The connective tissue in the fish muscle is less than that in mammalian tissue and the fibers are comparatively shorter. The tissue has different physical properties which results in a more tender texture of fish compared with meat. The myofibrils of fish muscles have a striated appearance similar to that of a mammalian muscle and contains the same major proteins, myosin, actin, actomyosin and tropomyosin.

Fish actomyosin has been found to be quite labile and easily changed during processing and storage. During frozen storage, the actomyosin becomes progressively less soluble and the flesh becomes increasingly tougher. Fish proteins are particularly susceptible to destabilization during freezing and frozen storage. After freezing, the fish may become tough, rubbery and lose moisture.

Studies on the effect of heat processing on fish indicate that the dietary value of protein seems not to be significantly affected by exposure to canning time/temperature processes. Infact, some proteinaceous components that would otherwise be plate-waste, like salmon and sardine bones, are softened enough to become edible. The heat denaturation of protein causes water losses varying from 9 to 28%, dependent on the severity of the process/pre-process, species, pH and other physiological factors.

Textural changes due to heat processing are also inevitable and may be advantageous to a limited degree. Excessive protein denaturation and the accompanying decrease in the water-holding capacity of the structural components yield a product with a dry and chewy mouth-feel. However, the oily-fleshed fish exhibit less of these effects, due to the restrictive effects of the lipids on water migration. Choice of raw material is important in this context, with less fresh fish losing more water and therefore, showing greater textural deterioration after processing.

We have already studied about browning in the section of fruits and vegetables. Can you recall which components were responsible for the reaction? Well, yes, sugars and amino acids. In case of fishes too, presence of sugars and amino acids may be responsible for the Maillard-type reactions during heat processing.

Proline is a prominent amino acid found in fish and may contribute to sweetness. The sugars ribose, glucose and glucose-6-phosphate are flavour contributors, as is 5-inosinic acid, which contributes a meaty flavour note. Volatile sulfur compounds contribute to the flavour of fish; hydrogen sulphide, methylmercaptan and dimethylsulfide may contribute to the aroma of fish.

Browning in canned fish is commonly associated with ribose. Undesirable colour changes in shellfish during canning often involve metal ions, for example, the blue discoloration of crab meat involves iron, whereas a black discoloration in prawns relates to copper content. Eels, abalone and albacore tuna; all undergo discoloration on processing, due to the high iron content of the raw material. Discoloration of this type is increased when the material is held in frozen storage prior to canning, because of the build-up of free sulphur in the tissue. Iron and free sulphur react together during heat processing, precipitating black iron sulphide on the sides of the container, in the fish itself and especially in any free liquid.

Slight losses of B-group vitamins, thiamine, riboflavin, nicotinic acid, folic acid and cyanocobalamine have been revealed in comparisons between fresh and canned fish.

Do you know what factors lead to spoilage of fish flesh? A difference in the composition of tissues among different species, climate, procurement and holding practices are amongst few of the important factors that lead to spoilage of fish.

Spoiling fish flesh, which becomes subject to excessive autolysins, may yield a heat-processed product with a pitted or honeycombed texture, although a restricted degree of proteolysis prior to processing, may result in a desirable softening of the texture of the finished product.

9.7 ALTERATIONS OCCURRING IN EGG

The quality, flavour, composition and functional properties of eggs are adversely affected more rapidly and to a greater extent by the speed and conditions of handling, uncoated shells, storage times and temperatures.

The nutritive value of frozen and dried eggs is essentially the same as that of fresh eggs. The drying or freezing processes do not cause any significant loss of nutrients. Properly stored, dried and frozen eggs show no subsequent nutrient loss. This observation can be substantiated by the following facts.

A comparison of hard-cooked and scrambled eggs showed that none of the methods had an advantage with respect to thiamine content. However, scrambled eggs had about 20% less riboflavin than hard-cooked eggs. The loss of threonine (an amino acid), was the same (0.22%) for both cooking methods.

Drying of eggs under normal conditions causes little loss of the nutritional properties of the eggs. Vitamin A, vitamin B, thiamine, riboflavin, pantothenic acid and nicotinic acid have been determined in dried whole egg and found to be essentially the same as that in fresh egg product. The protein value of dried eggs remains essentially unchanged. Adverse drying conditions or poor storage conditions could damage nutritional properties. However, any egg product without any off-flavour will probably have all its nutritional properties.

Generally speaking, egg products do not lose their heat coagulating properties during drying. If drying conditions are too severe, or if the storage conditions are adverse, whole egg and yolk products can lose solubility and this loss in solubility will coincide with a loss of heat-coagulating properties. One manifestation of excessive heat in drying of plain whole egg and plain yolk is an increase in their viscosity on reconstitution. Change in viscosity of dried plain yolk is much greater than in dried plain whole egg. Viscosity increase in the whole egg and yolk products can also be observed during storage. Reconstituted viscosity increases quite rapidly at the temperatures above 100^{o} F.

The density of egg products is not affected by dehydration. When a dried egg product is reconstituted to its natural solids, it has about the same density as the liquid, from which it was dried. Bulk density of the dried egg product can vary considerably, depending upon the methods and conditions of drying. Pan-dried egg products are much higher in bulk density than their spray-dried counterparts. Freeze-dried egg products are lowest in bulk density.

The changes in functional properties noted above, are undoubtedly caused by the changes that occur in the chemical properties of the various components of the egg. As you are already aware, the major component of egg white is proteins. Thus, any changes that occur in egg white during drying are apparently caused by changes in these proteins. Denaturation and coagulation of the proteins are considered to be the chemical changes, since they involve the unfolding of proteins, which exposes certain chemical groups, such as the sulfhydryl group, thus altering the chemical reactivity of the proteins. Since water is an integral part of the protein molecule, its removal may cause certain changes to occur in the properties of egg white.

The presence of glucose in eggs can cause chemical changes during drying, as well as during storage after drying. In egg white, the reaction involves the reducing or aldehyde groups of glucose and the amino groups of the proteins (Maillard reaction). This reaction results in the development of brown colour and a reduction in solubility. The reaction is minimized by drying to low moisture content and at lower pHs. Because glucose constitutes about 4% of the solids in egg white, almost all egg white that is dried, has had the glucose removed before drying.

The changes that occur in egg-yolk and yolk-containing egg products are apparently even more complex than those in the egg-white. Changes in yolk and whole egg product can also be caused by the reaction with glucose. In this case, glucose can react with the amino groups not only in protein but also in cephalin. The reaction with cephalin causes the development of off-flavours and off-odours during storage. The reaction can be prevented by the removal of glucose and is also inhibited by the addition of carbohydrates like sucrose.

The changes in viscosity of plain egg yolk and whole egg, as indicated previously, are apparently due to the changes in the lipoproteins. The lipids make up approximately 45% of whole egg solids and 60% of yolk solids, and thus play a predominant role in changes during drying. Of the lipids in egg yolk, 62% are glycerides, 33% phospholipids and 5% cholesterol. Of the phospholipids, lecithin is 73% and cephalin is 15%. The oxidation rate of cephalin is extremely rapid, being approximately 100 times that of lecithin. These phospholipids are bound together with protein and water is an essential part of this association. When water is removed, the balance is changed. In general, it is difficult to remove water from lipoproteins without causing changes in their properties.

Gelation, which occurs when yolk is frozen and thawed, is apparently due to the aggregation of yolk lipoproteins because of the imbalance and shift in water. Carbohydrates prevent increase in viscosity of yolk during drying and after drying and storage.

Check Your Progress Exercise 3

1. Fill in the blanks:

a) The myofibrils of fish contains proteins, namely ……………., …………………… , …………………… and ……………………… .

b) On freezing, the fish becomes ……………. , …………… and …….…….. .

c) Comparison between canned and fresh fish reveal differences in the loss of …………………..

2. State True or False. Also correct false statements.

a) Drying or freezing egg has no effect on the nutritive value of egg.

----

b) Hard cooked eggs were found to have greater thiamine content as compared to scrambled eggs.

----

c) Eggs lose their heat coagulating properties on drying.

----

d) Changes occuring in egg-white is caused due to presence of proteins in it.

----

e) Lipoproteins are responsible for causing changes in the viscosity.

----

3. How is Maillard reaction occuring in egg-white different from that in egg-yolk?

----

4. What do you understand by the term ‘Gelation’?

----

5. What is the effect of heat processing on fish?

----

6. Explain the process of browning in canned fish.

9.8 ALTERATIONS OCCURING IN CEREAL & CEREAL PRODUCTS, LEGUMES

You are already aware of the chemical composition of cereals and pulses. We will now look into changes occurring in these food products due to processing and storage.

We all know that cereals can be stored without loss of quality for 2 to 3 years, provided that the kernel moisture content (which is 20-24%) after threshing is reduced to at least 14%. The kernel consists of four parts: the seed coat (pericarp), the fruit coat (aleurone layer), the endosperm and the germ, or embryo. Figure 9.1 depicts these four parts.

Figure 9.1: Cereal grain

The aim of milling (the process including crushing and grinding) is to obtain preferentially a flour, in which the constituents of the endosperm cells predominate. The outer part of the kernel, including the germ and aleurone layer is removed. During milling of the wheat kernel, 5-8% of the starch granules are mechanically damaged. The extent depends both on the type and intensity of milling and on the hardness of the kernel - harder the structure (of the kernel), greater the damage. Since the rate of water absorption during dough making and the enzymatic degradation of starch increases with increasing damage, these are important for the baking process and desirable to a limited extent.

The chemical composition of the flour depends on the milling extraction rate. Increasing the rate of flour extraction decreases the proportion of starch and increases the amount of kernel-coating constituents such as minerals, vitamins and crude fibre. Comparing products of the same extraction rate, rye flour contains higher proportions of both minerals and vitamins than wheat flour. In case of some B-vitamins, such as niacin, this difference is well-balanced by the higher concentrations in wheat in comparison to rye kernels.

The commercial product, semolina, is made from the endosperm cells of hard durum wheat. Semolina keeps its integrity during cooking and is used mostly for pasta production. Since semolina is a milled flour of low extraction rate, it contains few minerals and vitamins.

During baking, the vitamins of the B-group are lost to different extents. In white bread, the losses amount to 20-50% of the thiamine, 6-14% of riboflavin and 0-15% of pyridoxine. The foamy texture of dough is changed into the spongy texture of crumb by baking. Starch degrades to dextrins, mono- and disaccharides at the relatively high temperatures to which the outer part of the dough is exposed. Caramelization and non-enzymatic browning reactions also occur, providing the sweetness and colour of the crust. The thickness of the crust is dependent on the temperature, baking time and type of baked products.

Substances that have high aroma values are of importance in white bread crust and crumb. In the crust, two heterocyclic compounds, furanol as well as 2-and 3-methylbutanol are responsible for the roasty, malty and caramel notes, while the autoxidation products of linoleic acid- methional and diacetyl are involved in the aroma of the crumb. If the dough is fermented for a longer time, 3-methylbutanol and 2-phenylethanol, which are formed by yeast, increase rapidly in the crumb and are responsible for the "yeasty" flavor impression.

Next, let us look at the changes occurring during milling of rice.
Rice milling involves the following processing steps: rough rice (paddy rice) → hull removal → brown rice → polishing to remove the bran coats (fruits and seed coats), the cuticle, the germ and the aleurone layer → rubbing–off or rice polishing to obtain the end product, white rice.

White rice, in comparison to brown rice, is low in vitamin content and in minerals as is evident from Table 9.1.

Table 9.1:Vitamin content of raw, white and parboiled rice

	B-Vitamins (mg/kg)		
	Thiamin	**Riboflavin**	**Niacin**
Raw Rice	3.4	0.55	54.1
White rice	0.5	0.19	16.4
Parboiled rice	2.5	0.38	32.2

A nutritionally improved product may be obtained by a parboiling process, originally developed to facilitate seed coat removal. About 25% of the world's rice harvest is treated by the following process:

Raw rice → steeping in hotwater, steaming in autoclaves, followed by drying and polishing → parboiled rice.

This parboiling treatment causes the following changes: the starch gelatinizes, but partly retrogrades again during drying. Enzymes are inactivated by the heat, causing inhibition of the enzymatic hydrolysis of lipids during storage of rice. The oil droplets are broken and lipids partly migrate from the endosperm to the outer layers of the rice kernels. Since antioxidants are simultaneously destroyed, parboiled rice is more susceptible to lipid peroxidation. In contrast, minerals and vitamins diffuse from the outer layers to the inner endosperm and remain there after the separation of the aleurone layer. Parboiled rice has a better cooking quality and there is a lack of pastiness in the cooked rice.

Now, let us look into certain alterations occurring in legumes due to processing. Toxic substances (e.g., cyanogenic glycosides and anti-nutritive factors, such as proteinase inhibitors, lectins etc.) present in some legumes, can be destroyed by suitable processing procedures, like heating.

The softening of legumes during cooking is due to the disintegration of the cotyledonous tissue in individual cells. This is caused by the conversion of native protopectin to pectin, which quickly depolymerizes on heating. The middle lamella of the cell walls, which consists of pectins and strengthens the tissue, disintegrates in this process.

Conversely, the hardening of legumes during cooking is due to cross linkage of the cell walls. The following reactions which can start even during storage at higher temperatures are under discussion as the cause of cross linkage. Calcium and magnesium phytates included in the middle lamella are hydrolyzedby the phytase present. Apart from meso-inositol and phosphoric acid, Ca2+ and Mg 2+ ions also released, cross link the pectic acids and thus strengthen the middle lamella. Pectin esterases, which demethylate pectin to the acid, promote the hardening of the tissue. In the case of legumes that are relatively rich in phenolic compounds and polyphenol oxidases, the formation of complexes between proteins and polyphenols should contribute to the strengthening of the tissue.

Sprouting of legumes causes partial breakdown of starch and proteins and contributes to better digestibility. The special flavour associated with sprouted legumes is an added advantage. It has been shown that sprouting causes hydrolysis of the oligosaccharides, which are responsible for causing flatulence of legumes.

9.8 ALTERATIONS OCCURRING IN NUTS, OILSEEDS AND SPICES

Some oilseeds have acquired a great significance in the large-scale industrial production of edible oils. You have already studied that most fats and oils consist of triacylglycerols which differ in their fatty acid compositions to a certain extent. Other constituents are the unsaponifiable fraction which make up less than 3% of fats and oils and a number of acyl lipids, e.g., traces of free fatty acids, mono- and di- acylglycerols.

Soybean and peanut (or groundnut) oils are of great economic importance. Refined soybean oil contains branched furan fatty acids in low concentrations which are rapidly oxidized on exposure to light. This can lead to the production of the intensive aroma substance, 3-methyl–2,4-nonandione, which along with diacetyl is involved in the occurrence of "bean-like, buttery, hay-like" aroma defect, called as *reversion flavor*. In the complete absence of light, soybean oil is relatively stable. The shelf life of the oil is also improved significantly by partial hydrogenation to give a melting point in the range of 22-28^{o}C or 36-43^{o}C. Such oils are utilized as raw materials for the manufacture of margarine and shortening.

Processing of fats and oils is significant in the removal of undesirable components present in the raw material. Refining process comprises of lecithin removal, degumming, free fatty acid removal, bleaching and deodorization to remove contaminants.

Now, we move on to the spices. You are aware that some plants in dried or in fresh form, with intensive and distinctive flavours and aromas are used as seasonings or spices. The aroma substances in most spices are present as essential or volatile oils, which are obtainable by steam distillation. The main oil constituents are either mono- and sesquiterpenes or phenols and phenol ethers. Black pepper contains 3-8% of piperine as the most important pungent substance. Pepper is sensitive to light. In the processing and storage of ginger, gingerol gets easily dehydrated to shogaol, increasing the pungency.

Spices are marketed unground or as coarsely or finely ground powders. The flavour is improved when the spices are ground using a cryogenic mill. After grinding, the shelf-life of spices is limited. Crushed spices rapidly lose their aroma and absorb aromas from other sources. Leaf and herb spices are dried before they are actually crushed. The loss of aroma substances depends on the spice and on the drying conditions. With regard to the aroma preservation, the best results are obtained by freeze drying, when the water content is reduced to 16%.

Check Your Progress Exercise 4

1. Fill in the blanks:

a) Cereals can be stored without loss of quality if kernel moisture content is reduced to atleast ------------------- .

b) The extent of milling damage depends on ------------------- and -----------------------

c) Semolina is made from --- .

d) --------------, ------------- and ---------------- contribute to the roasty, malty and caramel notes of crumb.

e) Fermentation of the dough for a longer time leads to the formation of ----------------------------- and ------------------------- .

2. How does chemical composition of flour varies with the milling extraction rate?

----

3. What are the changes that occur during :

a) baking of cereals

----

b) storage of bread

----

c) sprouting of legumes

----

4. What are the factors leading to softening and hardening of legumes during cooking?

----

5. Explain ‘reversion flavor’ in oils.

9.9 LET US SUM UP

In this unit, we studied about chemical, physical and nutritional changes that occur in foods during processing and storage. These alterations were discussed among a variety of food groups such as fruits and vegetables, milk and milk products, meat and poultry, fish, egg, cereal, cereal products and legumes, and nuts and oilseeds. A number of processes that occur as a result of such alterations were also dealt with, such as browning, caramelization, gelation etc.

You have also learnt about the perspective of food processing in the current scenario, that is, you came to know of the various desirable and undesirable changes that occur during processing of foods.

9.10 GLOSSARY

Autolysins **:** A substance, such as an enzyme, that is capable of destroying the cells or tissues of an organism within which it is produced.

Blanching : The process of exposing a food product to either steam or hot water for a short time, before being placed in packages and frozen or dried.

Browning : A chemical reaction that takes place between amino group and the sugar.

Canning : A process of preserving foods by sealing them in an air-tight vacuum containers for future use.

Cold Shortening : a phenomena in which there is a tendency for shortening of meat muscles and thereby toughness on subsequent cooking.

Cold shortening : A phenomenon, whereby, there is a tendency for shortening and toughness of meat muscles, when stored at a temperature of -10 to -15^{o}C.

Convenience foods : Any packaged dish or food that can be prepared quickly and easily as by thawing or heating.

Cryogenic Freezing : The freezing at very low temperatures, in which the products are exposed to sprays of liquid nitrogen or carbon dioxide at temperatures of minus 150 degrees F or below.

Dehydration : Complete removal of water under controlled conditions, in such a way that minimal changes occur in the food item.

Food processing : The process in which the perishable food materials are given a suitable physical or chemical treatment.

Freezing : Foods maintained in a frozen condition at a temperature of about -18 degrees C or below.

Gelation : Process of formation of a gel from a solution; solidification; solidifying of a liquid matrix due to internal bonding.

Homogenization : The action of making something uniform in composition.

Irradiation : The physical process of exposing an object, system, or a material to a high radiant energy for the sterilization or preservation.

Pasteurization : The act or process of heating a beverage or other food, to a specific temperature for a specific period of time in order to kill microorganisms that could cause disease, spoilage, or undesired fermentation.

Radiation Sterilization : The process of sterilizing carried out by means of radiation.

Reversion flavor : The rapid oxidation of branched furan fatty acids on exposure to light, leads to the production of an intensive aromatic substance, which along with diacetyl contributes to the bean-like, buttery, hay-like aroma defect.

Sterilization : The physical process of killing microorganisms, including pathogenic and the bacteria, vegetative forms and other spores on or in an inanimate object or material.

Sulfhydryl compounds : Compounds with a-SH group, found in many plant and animal enzymes.

Surface Tension : A state of stress at the surface of a liquid due to the attraction of the molecules for each other.

Syneresis : The separation of liquid from a gel that is caused by contraction or spontaneous shrinking.

Thawing : A process whereby heat changes something from a solid to a liquid.

Viscosity : It is the resistance to flow.

9.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

a) Cellulose; pectic substances

b) Starch

c) Anthoxanthins and anthocyanins

d) Pectic substances, starch, intercellular air

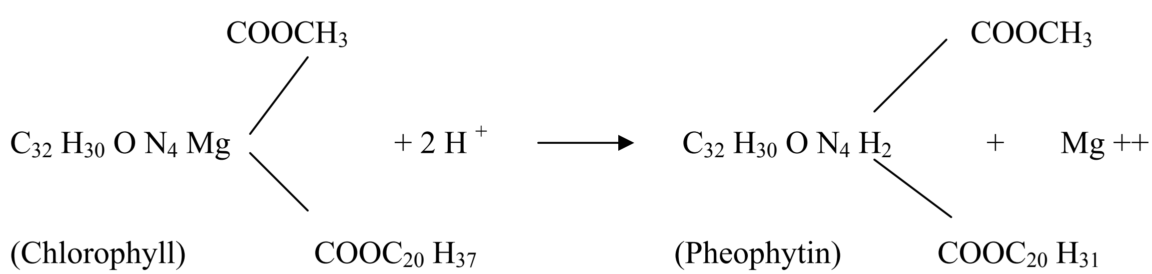
e) Pectinesterase

2.

a) Dehydration: Reduces the natural water content below the level critical for the microbial growth, concentrates major ingredients such as proteins carbohydrates and minerals. It leads to degradation of fats, maillard reaction and drop in vitamin levels. Original volatile aroma and flavour compounds are lost.

b) Freezing: Preservation/ moderate loss of vitamin A and carotenes. No effect on B-Vitamins, Vitamin C leaching by water or steam is detrimental. Irreversible textural changes occur in deep frozen vegetables.

3.



Check Your Progress Exercise 2

1.

a) False; Low temperature and aging are the factors that increase the viscosity of milk.

b) False; Autoclaving milk causes browning in milk

c) True

d) True

e) False; Surface tension of milk lowers with an increase in fat and protein

f) True

g) False; Radiation sterilization leads to decreased thiamine losses in pork than conventional thermal processing

h) True

2.

a) calcium caseinate

b) Sulfhydryl compounds

c) decreases

d) Pasteurization; Homogenization

e) Whole; skim

3.

a) Browning in heated milk: Heating milk to a higher temperature, such as 119^0C or higher leads to browning in milk. The brown colour is caused due to the heat effecting a change between the casein or amino acids and the sugar.

b) Cooked flavour in milk: Production of sulfhydrul compounds in milk at high temperatures leads to the formation of cooked flavour in milk.

c) Freezing alters the properties of milk: Freezing causes fat globules to lose their complete emulsion structure, to clump and become distorted and attain irregularity in shape and size. Casein, the milk protein gets precipitated as flakes.

4. Over-effective chilling of hot carcasses can lead to toughness. If the relationship between the refrigeration system and the bulk of meat exposed are such that temperature of muscles can be reduced below -10 to -15^{o}C, there is a tendency for shortening and thereby, toughness on subsequent cooking. This is referred to as cold shortening.

Check Your Progress Exercise 3

1.

a) Myosin, actin, actomyosin, tropomyosin

b) Tough, rubbery, lose moisture

c) B-group vitamins

2.

a) True

b) False; Hard cooked eggs had an equal Thiamine content as of scrambled eggs.

c) False; Eggs do not lose their heat coagulating properties on drying.

d) True

e) True

3. In egg white, the Maillard reaction involves the reducing or aldehyde groups of glucose and the amino groups of protein. While in yolk, the glucose reacts with the amino groups of not only protein but also in cephalin. This leads to development of off-flavours and off-odours during storage.

4. Gelation is a process which occurs when yolk is frozen and thawed. It is due to the aggregation of yolk lipoproteins because of the imbalance and shift in water.

5. No significant effect on the dietary values of protein, softening of certain proteinaceous component was observed as a consequence of heat processing. Water loss between 9 to 28%. Textural changes, excessive protein denaturation and decrease in the water-holding capacity.

6. Browning reactions occur in fish during heat processing. Sugars (ribose) along with amino acids are involved in browning reactions.

Check Your Progress Exercise 4

1.

a) 14%

b) Type and intensity of milling; hardness of the kernel

c) Endosperm cells of hard durum wheat

d) Heterocyclic compounds, furanol, 2- and 3- methylbutanol

e) 3- methylbutanol and 2- phenylethanol.

2. Increasing the rate of flour extraction decreases the proportion of starch and increases the amount of kernel coating constituents. Hence, varying the chemical composition of the flour.

3.

a) During the baking of cereals, there are losses of B-Group vitamins to different extent, B_1- 20 to 50%, B_2- 6 to 14% and B_6- 0 to 15%. The foamy texture of dough is changed into spongy texture of crumb. Degradation of starch to dextrins, mono- and disaccharides. Caramelization and non-enzymatic browning occur.

b) Storage of bread results in the moisture absorption which leads to loss in crispiness and glossyness of crust. Aromatic compounds of freshly baked bread evaporate. Changes in crumb structure are observed it becomes firm, loses its elasticity and juiciness.

c) Sprouting of legumes causes partial breakdown of starch and proteins and contributes to better digestibility. The special flavour associated with sprouted legumes is an added advantage. It causes hydrolysis of the oligosaccharides, which are responsible for causing flatulence of legumes.

4. The softening of legumes during cooking is due to the disintegration of the cotyledenous tissue in the individual cells. This is caused by the conversion of native protopectin to pectin, which quickly depolymerizes on heating. Hardening of legumes is due to crosslinkage of the cell calcium and magnesium phytates in the middle lamellae. Release of Ca++ and Mg++ with meso-inositol and phosphoric and cross links pectic acids and strengthen middle lamellae.

5. The rapid oxidation of branched furan fatty acids on exposure to light lead to production of the intensive aromatic substance, 3-methyl-2, 4-nonandione. This

alongwith diacetyl, contribute to the bean-like, buttery, hay-like aroma defect, which is called as reversion flavour.

UNIT -10 INTRODUCTION TO FOOD PROCESSING

Structure

10.1 INTRODUCTION

We are all aware that delay in the use of fresh foods, alters its freshness, palatability and nutritive value. Therefore, it becomes very important that we transform the fresh raw material and ingredients into wholesome, safe, nutritious and acceptable foods to be used by the consumers throughout the year. This process of transforming fresh, raw material into wholesome, safe, nutritious and acceptable foods for the consumers is referred to as food processing. Food processing is as old as the human hunger. Thousands of years ago, hunters and gatherers cured meat, dried fruits and berries, and cooked meals for their families. From the simple foods for ancient peoples to the foods created for astronauts, food processing has been intimately linked with human endeavors.

In this unit, we shall study about all the different aspects of processing i.e. its historical developments, what are the basic concepts and principles of food processing and preservation, why is food processing necessary, what are the different food processing techniques to prevent the food from the spoiling agents.

Using this knowledge of food processing, we shall then learn about how to transform the food into a more palatable form with a prolonged shelf-life. But, before we learn about processing we need to understand food spoilage and its causes. We begin this unit by first defining food spoilage and discussing the main causes of food spoilage.

Objectives

After studying this unit, you will be able to:

- discuss the concepts and aims of food processing
- describe the historical developments in food processing and preservation
- identify the factors that are responsible for food spoilage and
- describe the traditional methods of food preservation and their principles.

10.2 FOOD SPOILAGE AND CAUSES

Foods gradually undergo deterioration or spoilage from the time they are harvested, caught, slaughtered or manufactured. Therefore, delay in the consumption or processing of fresh foods alters its freshness, color, texture, palatability and nutritive value, organoleptic desirability, aesthetic appeal and safety. Essentially, all foods undergo varying degrees of deterioration during handling and storage. Some foods spoil rapidly, others keep for longer but for a limited period of time. Therefore, spoilage of food refers to *the alterations in foods or the food undergoes some physiological, chemical and biological changes, which renders it inedible or hazardous to eat.* Hence, such food is essential for processing or preservation after it is harvested or slaughtered.

Why and how does the food get spoiled? There are several causes of food spoilage. These include:

- *Growth of Microorganisms*, such as bacteria, molds and yeasts, which can spoil food very fast.
- *Action of Enzymes,* present in all raw food, promotes chemical changes affecting especially the food texture and flavor.

- *Atmospheric oxygen* can react with some food components, which may cause rancidity or color changes (oxidative reaction).

- *Damage due to pests (insects, rodents etc),* which account for huge losses in food stocks (Infestations).

- *Others*: moisture, light, time, temperature (heat and cold), mechanical damage, etc.

At any one time, many forms of spoilage may take place depending upon the food and environmental conditions. Food processing involves the development of preservation techniques to slow down or stop the food spoilage caused by the above factors and finally result in the preservation of food.

In the next section(s), we will learn about the processing concept, principles and methodology.

10.3 FOOD PROCESSING

Food processing, as you learnt earlier, involves the conversion of raw materials and ingredients into an acceptable food product for the consumer. It encompasses every aspect necessary to transport raw materials from the "harvest site" through packaging and merchandising. It involves the application of scientific principles to slow down or stop the natural processes of food decay caused by micro-organisms, enzymes in the food or environmental factors such as heat, moisture and sunlight and so preserve the food. Much of this knowledge is known traditionally and put into practice by experience and information handed down through the generations. Food scientists strive to improve the methods of storing, processing and manufacturing food through the scientific understanding of mechanisms involved.

The term 'processing' is very broad and encompasses many techniques. These include primary processing like threshing, dehusking, polishing and grinding in case of food grains, and preliminary operations such as cleaning, washing, sorting, grading, peeling, blanching and cutting in case of fruits and vegetables, and others to produce secondary processed products like breads, biscuits, confectionery, dehydrated and canned products like jams, jellies, pickles, sauces, frozen meals etc. This diverse range of operations means that the majority of foods are processed in one way or another before being consumed. What are the reasons for processing foods? Well, the reasons for food processing may vary, but the main objectives are discussed in the next section.

10.3.1 Aims of Food processing

The reasons for food processing may vary, but the main objectives are to:

- preserve the nutritive quality of food by preventing them from spoilage due to microbes and other spoilage agents,
- prolong the shelf-life (e.g. preservation). This is because the processed food is usually more stable than the raw food,
- enhance the quality (e.g. cooking),
- ensure that food is safe for future consumption,
- ensure the availability of many food products throughout the year,
- ease for storage, transportation and distribution systems, and
- create employment and to generate additional income.

Food processing, you would have realized, is practiced in some form or the other in most of our homes. Have you ever thought about its origin? How did it start? How did it develop? The next section presents the historical development of food processing. You will find this discussion interesting.

10.3.2 Historical development of Food processing

Food processing began thousands of years ago to help people keep food through the lean seasons. Various methods of preserving food have been around for a long time. The processes of smoking, drying (dehydration) and using salt and spices to prevent spoilage have been used for thousands of years. All of these methods were based on desiccation or dehydration. Grains and nuts were the first foods to be dried using the naturally available sunlight and air. Mechanical methods of drying were developed in the late 1700s. Dried foods are popular because they are compact, lightweight and last much longer than the fresh foods. Cheese-making was an accidental discovery, which became established as a method for increasing the longevity of milk.

The process of canning was pioneered in the 1790s when Nicolas Appert, a French Confectioner, discovered that the application of heat to food in sealed glass bottles preserved the food from deterioration. Napoleon-I gave Appert 12,000 Francs to make his invention public. Napoleon was highly interested in Appert's invention because of its potential to supply food to the armed forces who were many miles away from home. Appert published several books for canning and started the canning industry. Around 1806, the French Navy had undertaken successful training of Appert's principles on a wide range of foods including meat, vegetables, fruit and milk.

Before 1860, changes in food were explained on the theory of spontaneous generation. Pasteur demonstrated that ferments, molds and some other forms of putrefaction were caused by the presence of microorganisms widely distributed in the environment. Since these microorganisms are the main cause of food spoilage, food preservation depends on rendering conditions unfavorable for their growth.

The evolution of food processing is listed in Table10.1.

Table-10.1 Evolution of food processing

- 8000 - 7000 BC. Mankind first began farming, growing crops and raising animals for food instead of hunting and gathering for food.
- 4000 B.C. Salt, chemicals in smoke, drying, use of snow and ice were used for storing food for long times.
- 3000 B.C. Yeast was used to make alcoholic drinks by fermentation.
- 200 A.D. Bacteria were used to make yogurt by fermentation.
- 1810 Nicolas Appert (1752-1841) discovered a way of preserving food in sealed containers. Canning industry is developed from his discovery.
- 1860s Louis Pasteur (1822-95) invented a way of killing harmful microbes in wine and beer.

- 1920s Clarence Birdseye (1886-1956) developed a method of quick freezing food.

Today, food processing allows food from other parts of the world to be transported to our local market, so that we can enjoy a great variety of things to eat all through the year. Let us now study the methods and principles that are involved in the food preservation technique.

10.3.3 Methods and Principles of Food preservation

Food preservation is one of the oldest technologies used by human beings. The perishable food materials like fruits, vegetables, milk, meat, fish and others deteriorate or decay easily, so quite a lot of such commodities are wasted in various stages of food supply chain unless special methods are used for their preservation. Therefore, the process in which, the perishable food materials are given a suitable physical or chemical treatment to prevent their wastage, spoilage and to retain their nutritive value for long periods, is called food preservation. The principles of food preservation refer to *the processing techniques that are used to prevent food from spoilage*. The different preservation techniques commonly used today are given in the Table 10.2.

Table 10.2: Methods of food preservation

1. Asepsis, or keeping out microorganisms
2. Removal of microorganisms (filtration, centrifugation, washing, trimming)
3. Maintenance of anaerobic conditions, e.g., in a sealed, evacuated container
4. Drying (drying under the sun, mechanical drying, freeze drying, smoking)
5. Use of high salt or sugar content (sugaring, pickling, curing etc)
6. Use of acids
7. Fermentation
8. Use of low temperatures (refrigeration, chilling, freezing)
9. Use of high temperatures (pasteurization, boiling, canning)
10. Mechanical destruction of microorganisms, e.g., by grinding, high pressure, etc

11. Chemical preservatives
12. Carbonation
13. Irradiation
14. Combination of the two or more of the above methods.

All food preservation methods listed in Table 10.2 are based upon the general principle of preventing or retarding the causes of spoilage caused by microbial decomposition, enzymatic and non-enzymatic reaction, chemical or oxidative reactions and damage from mechanical causes, insects and rodents etc. The basic principles of the different preservation methods are given in Table 10.3.

Table 10.3: Principles of food preservation

1. *Prevention or delay of microbial decomposition:*
    a. By keeping out microorganisms (asepsis)
    b. By removal of microorganisms e.g. by filtration.
    c. By hindering the growth and activity of microorganisms e.g. by low temperatures, drying, anaerobic conditions or chemicals.
    d. By killing the microorganisms e.g. by heat or radiations.
2. *Prevention or delay of self-decomposition of the food:*
    a. By destruction or inactivation of food enzymes e.g. by blanching.
    b. By prevention or delay of chemical reactions e.g. prevention of oxidation by means of an antioxidant.
3. *Prevention of damage* because insects, animals and mechanical causes.

A detail discussion on the traditional methods of food processing is presented in section 10.4. Before you go on to read about these methods, look up the points to remember listed below. This will help you sum up what you have learnt so far.

POINTS TO REMEMBER

1. Conversion of raw materials and ingredients into acceptable consumer products is referred to food processing, which comprises of all the steps right from the time the raw materials are procured to the time it arrives on consumer tables, including preservation.

2. Most of the foods we buy are processed in some way or another. These processes help to make the products that are safe, of consistent quality and convenient for the consumers, prolonged shelf-life and available round the year.

3. Food spoilage or deterioration refers to the alterations in the foods or undergoing some physiological, chemical and biological changes, which render the food inedible or hazardous to eat. Food spoilage may affect: safety, nutritional value, organoleptic desirability, aesthetic appeal and change in color, texture, flavor and other quality attributes of the food.

4. Major causes of food deterioration: Growth of microorganisms (bacteria, yeasts, molds); activities of food enzymes and other chemicals within the food itself; infestation by insects, parasites, rodents; oxidation; time, temperature and light; physical stress or abuse.

5. The principles of food preservation refer to the processing techniques that are used to prevent food from spoilage caused by the above agents.

6. The origin of food processing goes all the way back to 8000 B.C. Smoking, drying, and salting were some of the most frequently used processes of preservation during ancient period.

Check Your Progress Exercise 1

1. Define food processing and food preservation.

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2. List the major causes of food deterioration/spoilage.

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3. What are the effects of food deterioration?

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4. Mention the major advantages of food processing.

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5. Different preservation techniques commonly used today, include:

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6. What do food manufacturers particularly aim to achieve when they preserve a food? (Choose the correct answer)

(i) To improve its vitamin C content.

(ii) To extend its shelf life.

(iii) To reduce the amount of cooking time it will require.

10.4 TRADITIONAL METHODS OF FOOD PROCESSING

Because food is so important to survival and most foods remain edible for only a brief period of time, people since the earliest ages have experimented with the methods for successful food preservation. Among the products of early food conservation, were cheese and butter, raisins, pemmican, sausages, bacon and grains. Therefore, food preservation is one of the oldest technologies used by human beings. Often, in the way of many traditional technologies, the ideas and methods are passed down through the generations, from mother to daughter. Look around and everywhere you will see people processing food, wherein food is being dried, crushed, milled, canned, bottled, cooked and sweetened.

Various methods of preserving food have been around for a long time. The methods like drying, pickling, salting, smoking, canning and freezing have been with us for the times immemorial. But all of these traditional methods are being updated and are in use today in some form. The methodology and principles of some of the preservation methods are discussed here:

- *Asepsis:* Food is a living system and it has natural protection mechanisms in its raw agricultural state. Once removed from the field or protective skin or peel (e.g. banana, coconut, vegetables, shell of nuts, husks of grains etc), it begins to deteriorate. Asepsis deals with the prevention of microbial contamination (keeping out microorganisms) of fresh or processed foods. Packaging of foods is a widely used application of asepsis.

- *Drying:* Drying is the oldest and probably the simplest way of preserving food. It is usually accomplished by the removal of water. Dried foods are preserved because the available moisture level is so low that the microorganisms cannot grow and enzyme activity is controlled. Moisture from food may be removed by a number of methods: drying by the Sun's rays and by the modern artificial ones. Grains and nuts were the first foods to be dried under the sun and air. However, sun-drying is a slow process, risk of contamination and spoilage and is limited to climates with a hot Sun and a dry atmosphere and to certain fruits such as grapes (raisins), figs, dates, apricots, raw mangoes (*amchur*), pears and peaches. Vegetables like beans, peas, cabbage, cauliflower, lady fingers, garlic, onions, chillies, turmeric and all leafy vegetables can also be dried by sun-drying. Drying of fruits and vegetables involves washing, peeling, preparing and spreading on flat bottom trays and drying under Sun. Fish (Bombay duck) and shrimps are dried by exposing them to the Sun on the seashore. The word dehydration usually implies *the use of controlled conditions of heating, with the forced circulation of air or artificial drying (mechanical drier)* as compared with the use of sun-drying. Using mechanical driers, fruits, fruit leathers, banana chips, tea, coffee, milk, soups, fish, meat, eggs and vegetables can all be dried year-round. Dried foods are compact and lightweight; do not require refrigeration and last much longer than the fresh foods. Dried foods should be stored in airtight containers to prevent moisture from rehydrating the products and allowing microbial growth.

- *Salting:* Salting, especially of meat, is an ancient preservation technique. Food is treated with salt or a strong salt solution. Due to high concentration of salt, water from the food is tied up and made unavailable for microbial growth and enzyme action and hence, preserved the food. Salt has the following effects: (a) it causes high osmotic pressure and hence, plasmolysis (shrinking) of cell; (b) it dehydrates foods by drawing out and tying up moisture as it dehydrates microbial cells; and (c) it ionizes to yield the chloride ion, which is harmful to organisms. Dry salting is used in India for the preparation of tamarind, raw mango, amla, fish and meat. Salted meat and fish can last for years. In meat salting, the prepared meats were soaked in 10% salt-water brine for several weeks. In fish salting, fresh fish were gutted on a cement slope and washed with the water. Coarse salt was then rubbed into their gills, mouth and scales. Layers of fish were alternated with layers of salt and covered with dry matting. They were then left to stand for 3 to 5 days, after which the pile was turned over and left for an additional 3 to 5 days.

- *Sugaring:* Water is withdrawn from the microbial cells when they are placed in a strong sugar solution (about 68%) and thus result in an adverse effect on microorganisms. Therefore, sugars such as glucose or sucrose, owe their effectiveness as preservatives to their ability to make water unavailable to organisms and to their osmotic effect. Examples of food preserved by high sugar concentrations are sweetened condensed milk, fruits in heavy sugar syrup (preserve or murraba), jams, jellies, marmalades and candies. Jam is prepared by boiling the fruit pulp with sufficient quantity of sugar (about 55 % by wt), acid and pectin to a reasonably thick consistency.

- *Pickling:* Pickling was widely used to preserve meats, fruits and vegetables in the past, but today it is used almost exclusively to produce "pickles" or pickled cucumbers or pickled onions and sauces. Pickling uses the salt combined with the acid, such as acetic acid (vinegar). Microorganisms do not grow well in acidic solutions. Some of the fruits and vegetables, which lend themselves to pickling, are raw mangoes, limes, amla, ginger, turmeric and green chillies. To make pickles, the fruits or vegetables are washed, cut into halves or quarters, the seeds are removed and then either dry salted or soaked in a 10-15% salt water brine for several days or months, then rinsed and mixed with spices, oils etc. and stored in glass bottles or jars.

- *Fermentation:* In contrast to other preservation methods, multiplication of microorganisms and their metabolic activities are encouraged. In this, microorganisms break down complex organic compounds into simpler substances either in aerobic or anaerobic conditions. The chemicals excreted by the microorganisms cause the preservative effect of fermentation. The principal chemicals involved are the acids (especially, lactic acid) and alcohol. These inhibit the growth of common pathogenic organisms in foods. Examples of food preserved by fermentation are yogurt, cheese, beer, wine and other alcoholic beverages.

- *Cheese-Making:* Cheese is a way of preserving milk for long periods of time. In this process, the milk in cheese becomes something completely unlike milk, but cheese has its own interesting and delicious properties. Cheese-making is a long and involved process that makes use of bacteria, enzymes and naturally-formed acids to solidify milk proteins and fats and preserve them. Cheese can be stored for months or years.

- *Smoking:* Smoking was known as a method of food preservation at an early date. Foods are exposed to smokes by burning some special kinds of wood. It has two main purposes, adding desired flavoring and preserving. In the earlier times, many households had smokehouses, which were used to smoke beef, ham and bacon. Smoking is still used to preserve fish and meat. Most meat is smoked after curing to aid their preservation. Preservative action is provided by such bactericidal chemicals in the smoke as formaldehyde and creosote, and by the dehydration that occurs in the smokehouse. The smoke is obtained by burning hickory or a similar wood like oak, maple, walnut and mahogany under low breeze/wind.

- *Cold Preservation:* The metabolism of a living tissue is a function of the temperature of the environment. Low temperatures are used to retard chemical reactions and action of food enzymes and slow down or stop growth and activity of microorganisms in the food. Lower the temperature, the slower will be the above natural activities. Freezing and refrigeration are among the oldest methods of preservation. Mechanical ammonia refrigeration systems invented during 1875 allowed development of commercial refrigerated warehousing and freezing. Low temperatures employed can be:

  (a) Cellar storage temperatures (about 15 ° C): It is usually used for the storage of surplus foods like root crops, potatoes, onions, apples, etc. for limited periods.

  (b) Refrigerator or chilling temperatures (0°C to 5°C): Foods kept at this temperature slows down the microbial activities and chemical changes resulting in spoilage. Mechanical refrigerator or cold storage is used for this purpose. Examples of this include meats, poultry, eggs, fish, fresh milk and milk products, fruits, vegetables, etc. can be preserved for 2-7 days by refrigeration.

  (c) Freezing (-18°C to - 40°C): In freezing, water in food turns into ice and makes unavailable for reactions to occur, and for microorganisms to grow. Most perishable foods like poultry, meats, fish, ice-creams, peas, vegetables, juice concentrates, etc. can be preserved for several months at this temperature. In vegetables, enzyme action may still produce undesirable effects on flavor and texture during freezing. Heating, like blanching, therefore, must destroy the enzymes before the vegetables are frozen.

- *Heat Preservation:* The process of heating was used centuries before its action was understood. Food is heated up or cooked. Heat kills microorganisms, alters the protein structure and destroys enzyme activity of microorganisms in food. The examples include all forms of cooked food, pasteurization, milk sterilized by UHT (ultra high temperature), canning, etc. One of the most important modern applications of the heat principle is the pasteurization of milk. Heat treatment of food may be in different ways:

(a) Pasteurization (temperature below 100° C)

Pasteurization is a heat treatment that kills a part but not all the microorganisms present and usually involves the application of temperatures below 100° C. Milk, for example, is usually heated to 63° C for 30 min or 71° C for 15 seconds or in UHT, 138° C for 2-4 seconds. Examples are: milk, wine, beer, fruit juices and aerated waters are routinely pasteurized. The heating may be by means of steam, hot water, dry heat or electric currents and the products are cooled promptly after the heat treatment. Pasteurization is usually supplemented by other methods to prolong shelf-life.

(b) Boiling (temperature at 100° C)

Cooking of rice, vegetables, meat, fish etc. at home is usually done by boiling the food with water and involves a temperature around 100° C.

(c) Canning (temperature above 100° C)

Canning is the process in which *the foods are heated in hermetically sealed (airtight) jars or cans to a temperature that destroys microorganisms and inactivates enzymes that could be a health hazard or cause the food to spoil.* The vacuum seal formed after heating and cooling in the process ensures that no microorganism can get into the product. The degree of heat and the length of time of heating vary with the type of food and the kinds of microorganisms that are likely to occur in it. High-acid foods such as fruits and tomatoes can be processed or "canned" in boiling water, while low-acid vegetables and meats must be processed in a pressure canner at 121 °C (15 psi pressure). Most canning is in 'tin cans' which are made up of tin-coated steel or in glass containers, but increasing use is being made of containers that are partially or wholly of aluminum, plastics such as pouches or solid containers. Examples of food preserved by canning are-all kinds of tinned foods, such as soup, meat, beans, cereal grains, legumes, nuts, and other various dried food products such as fruit, coffee, milk, soups, fish, meat and vegetables.

- *Food concentration:* Relatively few liquid foods are preserved by concentration, mainly because of the reduction in water activity (a_w) and development of osmotic pressure, which retard the microbial growth and enzymatic reactions. Concentration of food is usually done for many reasons: reduction in volume and weight; reduction in packaging, storage and transport costs; better microbial stability; and convenience. Examples of food preserved by concentration are tomato paste, fruit juice concentrate, soup and condensed milk. The main requirement to improve processing of these products is to control the rate of heating to prevent localized burning of the product, particularly when it has become thickened towards the end of boiling.

- *Carbonating:* Carbonated water is the water in which carbon dioxide gas has been dissolved under pressure. By eliminating oxygen, carbonated water inhibits bacterial growth. Carbonated beverages (soft drinks), therefore, contain a natural preservative.

- *Use of food Additives:* Food additives may be defined as *substances added intentionally to food, generally, in small quantities to improve its appearance, flavour, texture or storage properties*. These may be classified into different broad groups as listed in Table 10.4.

  Those food additives, which are specifically added to prevent the deterioration or decomposition of a food, have been referred to as *chemical preservatives*. In food preservation, the added substances may be grouped into two. The first one includes the use of sugar, salt, spices, acetic acid (vinegar) and alcohol, and is referred to as class I preservatives and is considered to be relatively safe to humans. The second group includes the use of benzoic acid, sulfur dioxide, nitrates and nitrites and a variety of neutralizers, firming agents and bleaching agents and referred to as class II preservatives and is considered to be relatively safe to humans, but within the permissible doses prescribed by the Food Regulatory bodies because higher concentrations can be a health hazard. Preservation of foods by the chemicals is effected by interfering with the cell membrane of the microorganism, their enzyme activity and genetic mechanism; by acting as antioxidants.

Table 10.4: Food Additives

Preservatives	Sodium benzoate in fruit drinks, potassium meta bisulphate in fruit products, sorbic acid in cheese, sodium and calcium propionates in breads and cakes, nitrates and nitrites in meats.
Antioxidants	Butylated hydroxy anisole (BHA), Butylated hydroxy toluene (BHT), propylgallate (PG), tocopherols in oily or fried foods; Ascorbic acid, SO_2 in fruit products.
Sequestrants (chelating agents)	Polyphosphates, citric acid – to remove elements from the food.
Surface-active agents (emulsifiers)	Lecithin, mono-and di-glycerides and bile acids-to stabilize oil in water.
Stabilizers and thickeners	Gums, gelatin, carboxy methyl cellulose, pectin, egg yolk, etc. in jellies, chocolate milk drinks, pie fillings and cake toppings.
Bleaching and maturing agents	Oxides of nitrogen, chlorine dioxide in bleaching and maturing flour.
Food colors	Natural sources: annatto, caramel, carotene, saffron, Synthetic: coal tar dyes.
Non-nutritive sweeteners	Saccharin, cyclamates, etc.
Flavouring agents and flavor enhancers	Monosodium glutamate (MSG), 5'-nucleotides

- *Food Irradiation:* Food irradiation is another sterilizing technique in which the foods are bombarded by high-energy rays called *gamma rays* or by fast-moving electrons to kill bacteria, fungi and insects and in some cases, to delay fruit ripening. It has been used in pasteurizing or sterilizing perishable foods such as meat, fish and fruits and extending their storage lives for long periods. It is also used for sprouting inhibition in onions, potatoes etc. Sterilization can be effected at room temperature and hence, the technique is also called as *cold sterilization* process. A major benefit of irradiation is that it can occur after the food is packaged and sealed. Cobalt-60 or Cesium-137 or electrons producing machines are the principal sources of ionizing radiations used for food irradiation. The unit of radiation is in terms of rads (and kilorad or megarad).

POINTS TO REMEMBER

1. The traditional food preservation methods like drying, pickling, salting, smoking, canning and freezing have been with us from the times immemorial. But all of these methods are being updated and are in use today in some form.

2. Dried foods are preserved, because the available moisture level is so low that microorganisms cannot grow and enzyme activity is controlled.

3. Fruits like grapes (raisins), figs, dates, apricots, raw mango (amchur), pears and peaches and vegetables like bean, peas, cabbage, cauliflower, lady finger, garlic, onion, chilli, turmeric and all leafy vegetables including fish can be dried under Sun.

4. Dried foods are compact, lightweight, do not require refrigeration and last much longer than fresh foods, retaining to wholesomeness.

5. Effects of salt in food preservation: (i) it causes high osmotic pressure and hence shrinking of cell, (ii) it dehydrates foods by removing moisture and

making it unavailable for the microbial cells; (iii) it ionizes to yield the chlorine ion, which is harmful to organisms.

6. Foods preserved by high sugar concentrations are sweetened condensed milk, preserves, jams, jellies, marmalades and cadies.

7. Foods preserved by fermentation are yogurt, curd, cheese, beer, wine and other alcoholic beverages.

8. Cheese making is a long and involved process that makes use of bacteria, enzymes and naturally formed acids to solidify milk proteins and fat and preserve them.

9. Preservative action of smoking is due to the bactericidal chemicals like formaldehyde and creosote present in the smoke and dehydrating effect.

10. Low temperature preservation of food may be at (i) Cellar storage temperatures (about 15° C); (ii) Refrigerator or chilling temperatures (0° C to 5° C); (iii) Freezing temperatures (-18° C to –40° C).

11. High temperature preservation of food may be at (i) Pasteurization temperature (below 100° C); (ii) Boiling temperature (at 100° C); (iii) Canning temperature (at or above 100° C).

12. Advantages of concentration of foods are- reduction in volume and weight hence, reduction in packaging, storage and transport costs; better microbial stability and convenience.

13. Chemical preservatives are referred to as those food additives, which are specifically added to prevent the deterioration or decomposition of a food.

14. Cobalt-60 or Cesium-137 or electrons producing machines are the principal sources of ionizing radiations used for food irradiation.

Check Your Progress Exercise 2

1. State whether the following statements are correct or incorrect. Correct the false statements.

(i) Asepsis deals with killing of microorganisms.

(ii) Food in its agricultural state has natural protection mechanism from deterioration.

(iii) Dried foods are more susceptible to microbial spoilage.

(iv) Preservation of food by high sugar and salt solution is based on the principle that water from food is tied up and made unavailable for microbial growth and enzyme action.

(v) The heat developed during the process causes the preservative effect of fermentation.

(vi) Cheese making is a process to preserve the milk into solid form for months and years.

(vii) Smoking is a method of food preservation mainly used for milk and milk products.

(viii) Preservation of food by cold temperature is due killing of spoilage microorganisms and inactivation of enzymes present in the food.

(ix) Pasteurization is the process of heat treatment to kill all the microorganisms present in milk or fruit juice.

(x) In canning preservation, high acid foods are processed at temperature above 100 C.

(xi) Sugar, salt, spices, vinegar and alcohol are considered as class I food preservatives relatively safe to humans.

(xii) Ionizing radiations are measured in terms of Kcal.

10.5 LET US SUM UP

In this unit you studied about the basic fundamentals of food processing. Food processing, you learnt, refers to the transformation of raw materials and ingredients into a more palatable, readily usable form, nutritious and convenience food product with a prolonged shelf-life.

We have also identified the several agents or factors responsible for food spoilage. To prevent the food from spoilage, we have discussed some of the traditional food processing methods like drying, salting, smoking, sugaring, fermentation, use of preservatives and use of heat treatment. In all of these methods discussed, the common basic principle is to slow down or stop the natural process of food spoilage caused by the various factors and so preserve the food. As a result, availability of food round the year, easy storage, transportation and distribution, retention of nutritive value of the food, creation of employment and generation of additional income are ensured by the technique of food processing. You also studied about the development of food processing. We have recorded that during ancient period, smoking, drying and salting were some of the most frequently used process of food preservation.

10.6 GLOSSARY

Acetic acid **:** Active ingredient in vinegar; used in food preservation.

Acid foods **:** Foods which contain enough acid to result in a pH of 4.5 or lower. Includes all fruits except figs; most tomatoes; fermented and pickled vegetables; relishes; and jams, jellies and marmalades.

Anearobic fermentation **:** Fermentation in the absence of air (secondary fermentation)

Antioxidants **:** Antioxidants are scavengers of particles called oxygen-free radicals. Vitamins A, E, C, and many of the carotenoids and phytochemicals are thought to be antioxidants.

Asepsis **:** keeping out microorganisms from food.

Blanching **:** The process of exposing a food product to either steam or hot water for a short time, before being placed in packages and frozen or dried.

Canning **:** A method of preserving food in air-tight vacuum-containers and heat processing sufficiently to preserve the food.

Cereals : Rice, wheat, millets and their products

Contaminant : an undesirable substance that is considered to make something impure or dirty.

Curing : a method of food preservation that involves soaking the food in a strong salt solution.

Dehydrating : a method of food preservation that involves removing the water from the food. (Drying food)

Dhals : decorticated, split products from pulse.

Drying Food : Drying is a method of food preservation that is simple, safe and easy to learn. Drying also creates new food products such as fruit leather, banana chips, pumpkin seeds and beef jerky.

Emulsifier : A substance that is used to prevent the liquids in an emulsion from separating into layers.

Enzymes : Protein molecules produced by living cells which act as catalysts in chemical reactions.

Fermentation : It is the transformation of sugars by intentional growth microorganisms (bacteria, yeast or mold). The fermentation of these sugars by yeast yields alcohol. This process takes place in big tanks, called fermenters.

Food additive : A substance added to food that enhance the palatability or preserve the foods.

Food spoilage : It occurs due to growth of microorganisms, action of enzymes present in the food, mechanical and insect damage to the food.

Freezer : A reach-in or walk-in food storage unit that maintains a temperature of 0°F (-18°C) or less.

Freezing : A method of food preservation involving low temperatures (-18° C), a change of state of a substance from liquid to solid.

Hermetic seal **:** An absolutely airtight container seal, which prevents reentry of air or microorganisms into packaged foods.

Infestation **:** invasion by insects and pests.

Irradiation **:** The treatment of food with ionizing radiation to kill microorganisms.

Low-acid foods **:** Foods, which contain very little acid and have a pH above 4.5. Vegetables, tomatoes, figs, all meats, fish, seafood and some dairy foods are low acid.

Oxidation **:** Reaction with the oxygen in the air, causes food to go bad

Pasteurization **:** A heating process designed to destroy the most heat-resistant pathogenic or disease-causing microorganism in a food product.

Perishable Food **:** Food product that spoils readily without special processing or preservation techniques e.g. meats, poultry, fish, shellfish, eggs, dairy products, and most fruits and vegetables.

Pickling **:** The practice of adding enough vinegar or lemon juice to a low-acid food to lower its pH to 4.6 or lower.

Preservative **:** a substance used to prolong the shelf life of foods or to prevent the spoilage of food.

Pulses **:** edible seeds of leguminous plants.

Rancidity **:** Development of any off or disagreeable flavors in oil or fat due to enzymatic or oxidative reactions.

Sterilization **:** A process that destroys virtually all microorganisms and their spores.

Yeast **:** The one-celled microorganism that turns sugar into alcohol and carbon dioxide.

10.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Food processing refers to the transformation of raw materials and ingredients into wholesome, safe, nutritious, convenience and acceptable food to consumers throughout the year.

   Food preservation refers to the process in which the, perishable food materials are given a suitable physical or chemical treatment to prevent their wastage, spoilage and to retain their nutritive value for long periods.

2. The major causes of food deterioration/spoilage are bacteria, molds, yeasts; enzyme present in food itself e.g. polyphenolase, lipase, peroxidase, Catalase; insects, rodents; oxidation, hydrolysis; Physical damage.

3. The effects of food deterioration are spoilage by pathogenic microorganisms can be injurious to health, nutrient loss, loss of organoleptic quality (colour, texture, taste, aroma), loss of functionality.

4. The advantages of food processing are many. Processing can prevent food deterioration or spoilage; processing can extend shelf-life (e.g. preservation); processing can enhance quality (e.g. cooking); processing can generate employment; processing ensures the availability of food round the year, safety, convenience and quality food products.

5. Asepsis; filtration, centrifugation, washing, trimming; drying and smoking; sugaring; pickling; curing; fermentation; refrigeration, chilling, freezing; pasteurization, boiling, canning; chemical preservatives; carbonation; Irradiation and combination of the two or more of the above methods.

6. (ii)

Check Your Progress Exercise 2

(i) True.

(ii) False. It deals with keeping out microorganisms

(iii) True

(iv) False. More susceptible to browning etc

(v) True

(vi) False. Lactic acid and alcohol excreted by the microorganisms

(vii) True

(viii) False. Meat, fish and their products

(ix) False. At low temperatures, retard chemical reactions and action of food enzymes; slow down or stop growth and activity of microorganisms in food

(x) False. Kills part but not all the microorganisms present.

(xi) False. Low acid foods are processed at temperature above 100° C.

(xii) True

(xiii) False. Measured in rads (and kilorad or megarad)

UNIT-11 METHODS OF FOOD PROCESSING – 1

Structure

11.1 INTRODUCTION

In the earlier unit we learnt about the principles and traditional methods of food processing. Now in the next two units we will find a detailed discussion on the different methods used today for food processing. Canning, dehydration, freezing, microwave processing, irradiation are common food processing methods used at home or at the industry level. Canning as a thermal processing method has been used for long. What does the process entail? What are the other thermal processing methods? These issues are discussed first in this unit, followed by a descriptive write-up on dehydration - one of the traditional methods of food processing. Freezing, microwave processing, irradiation and fermentation as other methods of food processing are taken up in the next unit.

Objectives

After studying this unit, you will be able to:

- enumerate the different methods of food processing
- enlist the different methods of thermal processing
- discuss the canning process and types of canned foods
- describe the different methods of dehydration

11.2 METHODS OF FOOD PROCESSING

Food is undeniably most vital to the survival of human beings. Hence, it must be processed using various scientific techniques. This is done to extend the shelf-life of foods as well as to ensure the quality and safety of the foods.

Over the years, several processing and preservation technologies have evolved, mostly by trial and error, for extending the storage life of food. As our scientific understanding of biological materials has accelerated in recent years so has the nature of the food industry, from a craft-based industry to a science-based manufacturing enterprise. Today, it is a big, dynamic, worldwide industry and undergoing continual change.

The fundamentals of food processing, as you may recall, involves the following two basic principles:

- Prepare the products fit for consumption.
- Destroy or inactivate pathogens found in food.

Based on these principles, the common unit operations for food processing include:

- Thermal processing: cooking, blanching, pasteurization, canning etc.
- Dehydration
- Cold preservation: refrigeration and freezing
- Fermentation
- Irradiation

We will learn about each of these operations in details, starting with thermal processing and dehydration in this unit.

11.3 THERMAL PROCESSING

Thermal processing *is the application of heat energy to the foods* with the following specific objectives:

- *Cooking:* Cooking is a primary process to make food more palatable and improve taste. This is not used as a preservation technique.
- *Blanching*: Blanching is defined as a mild heat treatment applied to tissue (usually plant) prior to freezing, drying or canning.
- *Pasteurization:* Pasteurization is a mild heat treatment to kill part of the microorganisms present in food. This process is usually combined with another preservation method. So primary objective of pasteurization is to kill pathogenic (milk) or spoilage (beers, fruit juices) microorganisms
- *Commercial Sterilization:* Sterilization is the most extreme heat treatment given for the preservation of food. Usually target organism is a heat resistant microorganism, most often a spore or schlerotia forming organism rather than a vegetative one (e.g. spore forming anaerobic bacteria – *Clostridium botulinum*)
- *Canning*: Canning is the process of applying heat to food that's sealed in a jar to destroy any microorganism that can cause food spoilage.

A brief description on each of the thermal processing method follows.

11.3.1 Cooking

All of us eat food either raw or in cooked form. Have you ever thought why we need to cook food? Cooking is a primary process to make food more palatable and improve taste. Note, this is not used as a preservation technique. You are aware of the various cooking methods used on day to day basis. At least six forms of cooking are available, namely:

1) Baking
2) Broiling
3) Boiling
4) Stewing
5) Roasting
6) Frying

While cooking, two preservation changes (at least) occur which include:

1. Destruction or reduction of microorganisms
2. Inactivation of enzymes

Other desirable changes that can occur during cooking include:

- Destruction of potentially hazardous toxins (endogenous, microbial)
- Alteration of color, flavor, texture
- Improved digestibility

11.3.2 Blanching

Blanching is used for variety of purposes. It is defined as *a mild heat treatment applied to tissue (usually plant) prior to freezing, drying or canning.* Why do we need to blanch foods?

Well, blanching is useful and its functions include:

- Inactivate most enzymes
- Some cleaning action
- Removes substances in some products
- Activates some enzymes (if controlled)
- Removes undesirable odors/flavors
- Softens fibrous material and decreases volume
- Expels air and respiratory gasses
- Preheating of product prior to canning

For frozen or dehydrated foods, major function is inactivation of enzymes, which can cause rapid changes in color, flavor and nutritive value. For canned products removing gases and preheating are very important to providing vacuum in can and proper sterilization.

Blanching as a pretreatment before drying has the following advantages:

- It helps in cleaning the material and reducing the amount of microorganisms present on the surface;

- It preserves the natural colour in the dried products; for example, the carotenoid (orange and yellow) pigments dissolve in small intracellular oil drops during blanching and in this way they are protected from oxidative breakdown during drying;
- It shortens the soaking and/or cooking time during reconstitution.

Next, do you know how to blanch foods? There are different methods of blanching food as highlighted in Figure 11.1. The hot water blanch methodology is presented in box 1. What ever the method used, remember blanching is usually carried out at high temperature for a short time. Time of exposure, temperatures vary with type of product and further processing.

a. Hot water blanching <100°C

b. Steam blanching > 100°C

Figure 11.1 Methods of Blanching

Box 1: Hot water blanching

A suitable water-blanching method in traditional processing is as follows:

- The sliced material is placed on a square piece of clean cloth; the corners of the cloth are tied together;
- A stick is put through the tied corners of the cloth;
- The cloth is dipped into a pan containing boiling water and the stick rests across the top of the pan thus providing support for the cloth bag.

The average blanching time is 6 minutes. The start of blanching has to be timed from the moment the water starts to boil again after the cloth bag has been dipped into the pan. While the material is being blanched the cloth bag should be raised and lowered in the water so that the material is heated evenly. When the blanching time is completed the cloth bag and its content should be dipped into cold water to prevent over-blanching. If products are over-blanched (boiled for too long) they will stick together on the drying trays and they are likely to have a poor flavour.

During hot water blanching, some soluble constituents- water-soluble flavours, vitamins (vitamin

C) and sugars - are leached out. With potatoes this may be an advantage as inactivation of enzymes (catalase and peroxidase) makes the potatoes less prone to turning brown.

Next, can you name a few foods which are best blanched? Yes, green beans, carrots, okra, turnip and cabbage should always be blanched. On the other hand, blanching is not needed for onions, leeks, tomatoes and sweet peppers. You may have noticed that tomatoes are dipped into hot water for one minute when they need to be peeled but this is not blanching. Another practice you may have notices is to use or add sodium bicarbonate to the blanching water when okra, green peas and some other green vegetables are blanched. Have you wondered why? The chemical raises the pH of the blanching water and prevents the fresh green colour of chlorophyll being changed into pheophytin, which is unattractive brownish-green.

Finally, let us learn how to evaluate blanching efficiency? Normally, two of the more heat resistant plant enzymes, namely peroxidase and catalase are used to evaluate blanching efficacy. If both these enzymes are inactivated, it can be safely assumed that most other enzymes are also destroyed. Remember, blanching is a delicate processing step; time, temperature and the other conditions must be carefully monitored. Blanching time to inactivate enzymes are dependent on:

1. Type of food
2. Method or type of heating
3. Product size
4. Temperature of heating medium

In case of steam blanching, the food product is directly exposed to steam in place of using water as a medium for blanching, which avoids the loss of food soluble solids (flavours, vitamins, acids, sugars etc.) to blanching medium as well as solves the problem of disposing blanching medium after processing.

11.3.3 Pasteurization

You must be aware of the various pasteurized products available in the market. The most commonly used product being ‘milk’. Why do we need to pasteurize food? What does pasteurization entail? Let’s find out.

Basically, *pasteurization is a mild heat treatment to kill part of the microorganisms present in food.* So, the primary objective of pasteurization is to kill pathogenic (milk) or spoilage (beers, fruit juices) microorganisms. This process is usually combined with another preservation method. Typical other methods used in combination with pasteurization include:

1. Refrigeration as in the case of milk
2. Chemical additives - pickles, fruit juices
3. Fermentation (additives) - sauerkraut, cheeses
4. Packaging (anaerobic conditions) - beers, fruit juices

The severity of heat treatment for pasteurization depends on:

1. *Heat resistance of target microorganism*. Typical target organisms include *Coxiella burnetti*, a pathogenic rickettsia in milk, yeasts and molds - in high acid foods and fermented products and yeasts - in fermented beverages
2. *Sensitivity of product to heat treatment:* For many foods use of **H**igh **T**emperature **S**hort **T**ime (HTST) treatment is recommended, which destroys pathogenic microorganisms, but does not do too much damage to food quality.

Further, there are a few other physical and chemical factors which influence the pasteurization process. These include:

a. Temperature and time;
b. Acidity of the products;
c. Air remaining in containers.

For pasteurizing two categories of processes may be used as indicated in figure 11.2

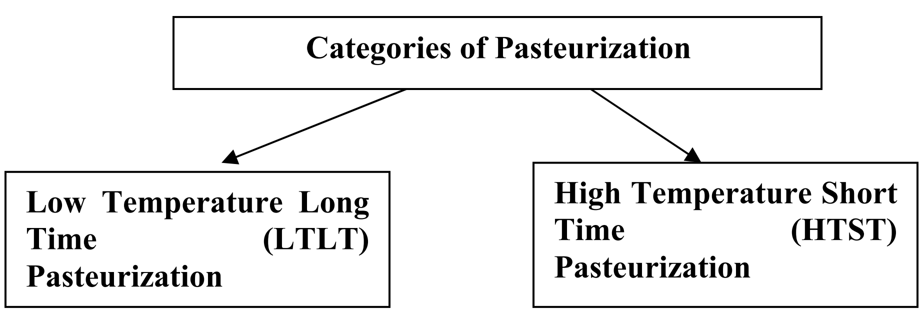


Figure 11.2 Categories of pasteurization

A discussion on each process follows:

a) *LTLT pasteurization*: In LTLT pasteurization, the pasteurization time is in the order of minutes and related to the temperature used; two typical temperature/time combinations are used: *63 to 65°C over 30 minutes or 75° C over 8 to 10 minutes*.

In this first category of pasteurization processes 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.

You would notice that, pasteurization temperature and time will vary according to:

- Nature of product; initial degree of contamination;
- Pasteurized product storage conditions and shelf life required.

b) *HTST pasteurization*: Rapid, high 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 may be: *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. Such short holding times, however, require special equipment which is more difficult to design and generally is more expensive than the 63-65°C/30 minutes type of processing equipment.

In flash pasteurization the product is heated up rapidly to pasteurization temperature, maintained at this temperature for the required time, then rapidly cooled down to the temperature for filling, which will be performed in aseptic conditions in sterile receptacles. Taking into account the short time and rapid performance of this operation, flash pasteurization can only be achieved in continuous process, using heat exchangers. Industrial applications of pasteurization process are mainly used for the preservation of fruits and vegetable juices and especially for tomato juice.

The pasteurization of products packed in glass containers leads to a problem of a specific nature, which is referred to as ‘thermopenetration’. What is the thermopenetration concept? Let’s find out.

The thermopenetration problem is extremely important, especially in the case of the pasteurization of products packed in glass containers, because it is the determining factor for the success of the whole operation. During pasteurization it is necessary that a sufficient heat quantity is transferred through the receptacle walls; this is in order that the product temperature rises sufficiently to be lethal to microorganisms throughout the product mass.

The most suitable and practical method to speed up thermopenetration is the movement of receptacles during the pasteurization process. Rapid rotation of receptacles around their axis is an efficient means to accelerate heat transfer, because this has the effect, among others of rapidly mixing the contents. The critical speed of for this movement is generally about 70 rotations per minute (RPM). This enables a more uniform heating of products, reducing heating time and organoleptic degradation.

Heating may precede or follow packaging. It is convenient to separate heat preservation practices into two broad categories: one involves heating of foods in their final containers, the other employs heat prior to packaging. The latter category includes methods that are inherently less damaging to food quality, where the food can be readily subdivided (such as liquids) for rapid heat exchange. However, these methods then require packaging under aseptic or nearly aseptic conditions to prevent or at least minimise recontamination. On the other hand, heating within the package frequently is less costly and produces quite acceptable quality with the majority of foods and most of our present canned food supply is heated in the package. Tetra pack available in the market for fruit juices are the best example for aseptic packaging.

11.3.4 Commercial Sterilization

Sterilization is the most extreme heat treatment given in preservation of food by heat. Usually target organism is a heat resistant pathogenic microorganism, most often a spore or schlerotia forming organism rather than a vegetative one. Common examples include *Clostridium botulinum*-a spore forming anaerobic bacteria and Putrefactive anaerobe. The basic characteristics of these microorganisms are highlighted in box 1.

Clostridium botulinum	Putrefactive anaerobe (PA) 3679 and FS 1518 *Clostridium sporogenes*
• Can grow and produce toxin at pH > 4.6 • Obligate anaerobe, spore-forming, heat resistant pathogens. • Assumed to be ubiquitous in soil. • Has several strains. Types A and B are most heat resistant. • Ingestion of toxins produced them causes food poisoning. • Toxins are destroyed at 100°C for 10 minutes.	• Non-toxic facultative anaerobe. • Resistance to heat similar to *Clostridium botulinum.* • Generally used to determine safe thermal processes instead of *Clostridium botulinum.*

It is important to remember that bacterial destruction is a logarithmic function, complete destruction not probable to make food commercially sterile for extended shelf-life at room temperature. *Hence, only 90 % destruction is aimed and this is called commercial sterility.* Thermal conditions that are needed to produce commercial sterility depends on:

1. Nature of the food
2. Storage conditions post processing
3. Heat resistance of target organism
4. Heat transfer characteristics of food, container and heating medium
5. Initial load or quantity of organisms present

Of these, the nature of the food, primarily the pH of food, is the most significant determinant of how severely the food will be processed. Based on the pH, therefore, all foods can be divided into three categories as highlighted in Table 11.1.

Table 11.1: Classification of foods based on pH

High Acid Foods	Low Acid Foods	Acid Foods
Those foods with pH < 3.7 Thermal processes are based on the destruction of • yeasts and molds. • Spore former do not grow at pH < 3.	Those foods with pH > 4.5 *Examples:* Asparagus, beans, corn, potatoes, cauliflower, cantaloupe, watermelons, banana	Those foods with pH of 3.7 to 4.5 *Examples* include: Apples, blueberries, peaches, tomatoes, orange, grapefruits, grapes Thermal processes are based on the destruction of • *Bacillus coagulans* • *Bacillus polymyxa*

It is also important to note that to determine a heating process for a particular food, we must determine the:

A. Destructive effects of heating on target organism (and food), and

B. The rapidity of food heating up.

Most food components and microorganisms obey first order reaction kinetics, which means that the destruction rate is dependent on initial concentration. We can find a heat treatment, which will take care of the target microorganism while allowing only minimal quality damage to food components. To determine thermal resistance of a microorganism at a specific temperature, the following steps are required:

- Heat at constant "known" temperature for different times.
- Recover surviving cells.
- Plot survival curve - e.g. time versus number survivors.

As line transverses one log cycle of survivor number represents a 90% reduction in number of survivors - because this is a first order reaction - this % reduction remains constant i.e. for the next log cycle another 90% reduction occurs. The time required to reduce one-log cycle of survivor at a particular temperature is known as *D-value* at that temperature.

The sterility index is represented by F value. This index often has a subscript representing the specific temperature and a superscript indicating the z value of the particular organism (F temperature change required to change the thermal death time by a factor of 10) thus represents the F value of *C. botulinum* at 121.1 (250°F). The temperature of 121°C is usually used as a reference temperature and is always indicated as "Fo". Since similar first order reactions occur for various food nutrients and qualities, a similar procedure can be used to analyze their loss as "thermal resistance curves". Another useful system for representing temperature response by biological systems is the Q value, which is the change in reaction rate for a 10°C temperature change.

The F value for *C. botulinum* is the time required to reduce by 12 D the number of viable spores and this has become the Standard Heat Process for foods which have the potential to have *C. botulinum* outgrowth (i.e. pH > 4.5). For a temperature of 121°C,

Fo = 12 D = 2.45 minutes = Sterilizing Value.

This is the **12 D concept** for canning operations. Thus if there were 10^{12} spores present in a can of food and it received a 12 D process, then there would be only 1 spore left. There are some food spoilage organisms that are more thermally resistant than *C. botulinum*. For foods that contain these microorganisms and for foods with pH > 4.5, processors typically process to 5 D. This would give a probability of loss due to spoilage of less than 1 can per 1000 for normal contamination.

While on the topic of sterilization, we also need to highlight that the following two methods of heat sterilizing foods are employed.

1. Foods can be heat sterilized then placed into a sterile container - aseptic processing
2. Foods can be placed into a non-sterile container then the entire container is processed - conventional canning

These steps are commonly done at the food canning establishments, where the actual processing is done. We will learn more about the canning process in the next sub-section.

Before we move on to canning, we need to emphasize here that like thermal destruction of microorganisms, thermal destruction of enzymes is also carried out during sterilization. Heat process for enzymes are carried out for the inactivation of enzymes. While enzymes or microorganisms are killed, the quality attributes of the food are also being destroyed or lost in a similar logarithmic manner. Ideally, if a troublesome enzyme is to be inactivated, heating the food product just enough to disrupt it without too much damage to the desirable quality attributes is preferred.

Check Your Progress Exercise 1

1. Fill in the blanks:

(i) The two basic principles of food processing are-------------------- and ---------------------- .

(ii) The application of heat energy to foods is referred to as ----------------------------------- .

(iii) Any two changes that occur in food on cooking are -- and --- .

(iv) --------------------- is the determining factor for the success of pasteurization process.

(v) Change in reaction rate for a 10^0C temperature change is referred to as ---------------------

2. What do you understand by the term blanching? What are the functions of blanching?

----

3. List a few benefits of blanching.

----

4. What do you mean by the term ‘pasteurization’? Also, explain the types of pasteurization.

----

5. List a few of thermal conditions required to produce commercial sterility.

Let us learn about the canning process.

11.3.5 Canning

You must have seen the markets flooded with canned products. Can you name a few of such products? Yes the canned juices, canned aerated drinks or the canned fruits etc. Have you ever given a thought to how canning of foods is done? Well read the following section and get to know all about canning and its uses.

It is in 1795 that *Nicolas Appert* (1749-1841), French cook-confectioner (figure 11.2), developed a process to preserve food during several months. The principle was to condition food products thermetically and to sterilise them with heat (100°C). The process was called canning and is defined as *a process for conservation of food and its nutritional qualities for long duration at ambient temperature, obtained by a process associating a heat treatment and a waterproof packing*. In simple terms*, canning is the process of applying heat to food that's sealed in a jar/can to destroy any microorganism that can cause food spoilage.*

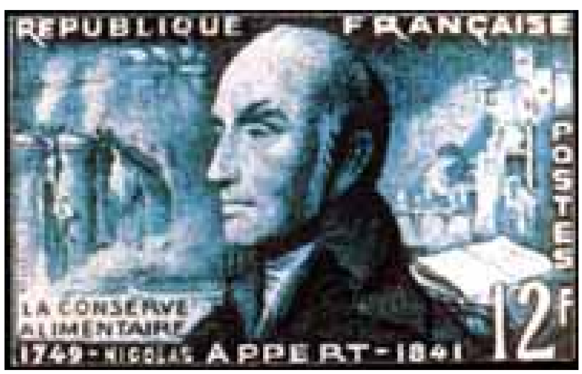


Figure 11.2: Nicolas Appert

Based on *Appert's* methods of food preservation the packaging of food in sealed airtight tin-plated wrought-iron cans was first patented by an Englishman, *Peter Durand*, in 1810. A can of roast veal taken on *Parry's* voyage to the Arctic in 1824 is highlighted in figure 11.3.

Figure 11.3: Can of Roast Veal

Since Parry's voyage in 1824, there are an enormous variety of canned foods available today, which differ both in terms of type of ingredients and method of processing used. The main types are as follows:

Types of canned foods:

1. Some foods form convection currents when being heated inside a can and so are heated faster since self-mixing - as foods become more viscous this mixing action is reduced (e.g. fruit juices, milk, brine packed vegetables, syrup packed fruits, gravies)
2. Some foods can only be heated by conduction - no currents are formed and heat must be passed from one molecule of food to the next toward the center - these foods heat very slowly (e.g. Thick purees, mash packs, layered products like spinach)
3. Some foods change modes during heating from convection to conduction - foods which contain large amount of starch which gels on heating - gives "broken heating curve" (e.g. cream style corn, condensed soups)

For conduction heated food, the slowest heating point "cold point" is the geometric center of the can. For convection heated food, the slowest heating point is along the vertical axis near the bottom of the can.

Let us next learn about the process of canning.
(refer to Figure)

Process 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 240-250°F (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.

Canning uses metal or glass containers into which food is placed and sealed under reduced atmospheric pressure. Food does not completely fill the container; a *headspace i*s required for expansion of food during heating. The headspace cannot be more than 10% of the total container volume. The containers are then processed in steam or hot water at temperatures above 115°C after which they are cooled. The cooking vessels required for these high temperature cooks must be capable of handling steam at pressures in excess of 1 atmosphere (14.7 psi). To have a steam environment at a temperature greater than 100°C elevated pressures are used.

Still Retorts are used in canning plants for heating foods in glass containers or different sizes of cans. These retorts are usually cylindrical in shape and may be oriented vertically or horizontally with a heavy lid or door on top or at one end. Containers are loaded in layers into perforated retort baskets or crates. This may be done manually or by machine. Filled crates are placed into the retorts, the lid is closed and steam is introduced. Water with steam injection is used for glass containers since they cannot handle the heat stress. An overriding air pressure maintains enough pressure so that the water does not “boil” at temperatures greater than 100°C. Temperature in a retort is regulated by means of a steam automatic valve. At the end of the “cook” cycle, the retort is showered/flooded with cold water (metal cans) or injected with cold water just below the surface of the hot water (glass jars). The containers are removed once they are cooled.
The sequence of operations employed in canning are highlighted in the next section. This will give you a good idea as to what canning as a procedure involves.

Sequence of operations employed in Canning

In a simplified manner, the main operations employed in canning can be described as follows:

Food preparation	Preparation procedures will vary with the type of food. For fruit, washing, sorting, grading, peeling, cutting to size, pre-cooking and pulping operations may be employed.
Can/receptacle	This may be carried out manually or by using sophisticated filling machinery. The ratio of liquid to solid in the can must be carefully controlled and the can must not be overfilled. A headspace of 6-9 mm depth (6-8% of the container volume) above the level of food in the can is usual.
Vacuum production	This can be achieved by filling the heated product into the can, by heating the can and contents after filling, by evacuating the headspace gas in a vacuum chamber, or by injecting superheated steam into the headspace. In each case the can end is seamed on immediately afterwards.
Thermal processing	The filled sealed can must be heated to a high temperature for a sufficient length of time to ensure the destruction of spoilage micro-organisms. This is usually carried out in an autoclave or retort, in an environment of steam under pressure.
Cooling	The processed cans must be cooled in chlorinated water to a temperature of 37°C. At this temperature the heat remaining is sufficient to allow the water droplets on the can to evaporate before labeling and packing.
Labeling and packing	Labels are applied to the can body and the cans are then packed into cases.

So now you can appreciate how interesting and scientific this whole process of canning is. In the end, can you also suggest what are the advantages of canning food? Try listing them down and tally your responses with the advantages listed herewith.

The main advantages of canned foods are: (a) they are safe and hygienic and have reasonably good nutritional value; (b) they are economical as the entire contents can be eaten, whereas

30~50% of fresh food cannot be eaten due to perishing and loss in weight; and (c) they come in a wide assortment, from main dishes to side dishes and desserts, and have utility value; and (d) they keep for a long period.

With canning, we come to the end of the thermal processing method.

11.4 DEHYDRATION

The technique of drying is the oldest method of food preservation practiced by mankind. The removal of moisture, which is actually dehydration or drying, prevents the growth and reproduction of microorganisms causing decay and minimizes many of the moisture mediated deterioration reactions. Further, removal of moisture brings about substantial reduction in weight and volume, thus minimizing packing, storage and transportation costs and enable storability of the product under ambient temperatures. The sharp rise in energy costs has promoted a dramatic upsurge in interest in drying worldwide over the last decade.

What then is dehydration? What is the theory/principle behind this method of processing? How are foods dehydrated? These are a few aspects which we will learn about now in this section..

Theory/Principle of Drying

Drying can be defined as the application of heat under controlled conditions to remove the majority of the water normally present in a food by evaporation. The main purpose of dehydration is to extend the shelf life of foods by a reduction in water activity (a_w). This will inhibit microbial growth, however the processing temperature will not normally be sufficient to cause inactivation, thus care will needed to be taken with the product on subsequent rehydration. Drying does cause deterioration in the eating quality and nutritive value of the food. The role of the food engineer is to design a plant that will minimize such detrimental effects while obtaining efficient drying rates. Typical foods that are important commercially include; sugar, coffee, milk, potato, flour, beans, pulses, grains, nuts, breakfast cereals, tea and spices.

From our discussion above, it is clear that dehydration deals with reduction in the moisture content of foods. In this context, therefore, understanding where and how the water is present, and assessment of moisture content in foods becomes crucial. These are the aspects discussed in the next section.

11.4.1 Expression of Moisture Content

Moisture content, you would realize, is expressed in one of two ways i.e dry weight basis (dwb) or wet weight bases (wwb). Moisture content is calculated using the following formula:

$$m.c.(m) = \frac{\text{mass of water}}{\text{mass of sample}} \text{ x } 100$$

where mass of sample can be made up of water and dry matter or solids. Thus

$$m.c.(m) = \frac{\text{mass of water}}{\text{mass of water} + \text{solids}} \text{ x } 100$$

On a dry weight basis, moisture is calculated as

$$M = \frac{\text{mass of water}}{\text{mass of solids}}$$

The mechanism content on wet basis can be converted to dry basis vice versa using the following equations:

$$\text{m} = \frac{100\text{M}}{1 + \text{M}} \text{ or M} = \frac{\text{m}}{100\,(1 - \text{m}/100)}$$

Moisture content (w.w.b.) is most often used in food composition tables, whereas moisture (d.w.b.) is more often encountered with sorption isotherms and drying curves. You will learn about sorption isotherms in Unit , Block of this course. Next, how to determine the moisture content of foods? The amount of water in a food is most easily determined by taking a representative sample of the food and drying it in an oven to constant mass.

Next crucial aspect to learn, in the context of dehydration, is about the types of water present in food. This information will help you understand the mechanism of drying, which is discussed in the next section. So read it carefully.

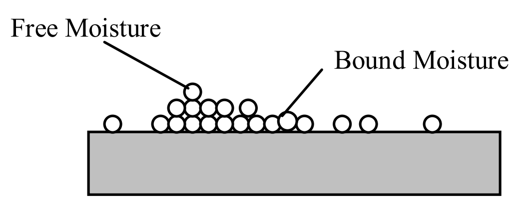
11.4.2 Classification of Types of Water Found in Food

Water may be present in several different forms in the food as highlighted herewith:

Water of hydration: This moisture is chemically bound to the constituents of the material and in most cases would not be considered in moisture content determinations. It is considered to be an integral part of the material.

Bound Water: Water which is in some way bound to the food so that it exerts a vapour pressure less than that of pure water. It can often be thought of as the first layer of water molecules attached to a surface.

Free Water: Water which is bound by such minute forces, that its vapour pressure is equal to the vapour pressure of pure water. It can be found as free water, in cavities and wide capillaries. This can often be thought of as the second and subsequent layers of moisture attached to a surface. The heat of adsorption of this moisture is equal to the normal heat of vaporisation of water at the same temperature.



Absorbed Moisture: It is the moisture that has passed through cell walls and entered the cytoplasm of the cell. It is this form of water that is believed to account for the hysteresis between the sorption and desorption equilibrium moisture content isotherms, described later.

The absorption of water by an organic, chemically inert material is a complex process which is not entirely understood. This complexity becomes much greater when biological materials are involved. This complexity is due principally to the fact that water may be present in several different forms as highlighted above.

With the basic understanding of moisture content and dehydration in general, let us now look at the mechanism of drying.

11.4.3 Mechanism of Drying

Drying as a mechanism, you will realize, involves the removal of free moisture from the surface and also moisture from the interior of the material. How does this mechanism work? When hot air is blown over a wet food, heat is transferred to the surface, and the latent heat of vaporisation causes water to evaporate. Water vapour diffuses through a boundary film of air and is carried away by the moving air. This creates a region of lower water vapour pressure at the surface of the food, and a water vapour pressure gradient is established from the moist interior of the food to the dry air. This gradient provides the driving force for the removal of water from the food. Water moves to the surface by the following mechanisms:

1) Liquid movement by capillary forces.
2) Diffusion of liquids, due to differences in concentration of solutes in different regions of food.
3) Diffusion of liquids that are adsorbed in layers at surfaces of solid components of the food.
4) Water vapour diffusion in air spaces within the food caused by vapour pressure gradients.

So you have seen that dehydration involves the application of heat to vapourise water and some means of removing water vapour after its separation from the food. Hence it is a combined/simultaneous (heat and mass) transfer operation for which energy must be supplied. A current of air is the most common medium for transferring heat to a drying tissue and convection is mainly involved. In order to assure products of high quality at a reasonable cost, dehydration must occur fairly rapidly.

Four main factors affect the rate and total drying time, which include:

- The properties of the products (the moisture content, surface area to volume ratio, surface temperature and rate of moisture), loss especially particle size and geometry;
- The geometrical arrangement of the products in relation to heat tansfer medium (drying air);
- The physical properties of drying medium/ environment;

- The characteristics of the drying equipment/drier (the dry bulb temperature, relative humidity).

Other factors which influence the rate of drying include:

1) The fat content of the food-Higher fat contents generally result in slower drying as moisture is trapped within the food.
2) The method of preparation- Cut surfaces loose moisture more rapidly than through skin.
3) The amount of food placed in a drier in relation to its size- In a given drier, faster drying is achieved with smaller quantities of food.

So far we have looked at the concept, theory and mechanism of dehydration. A wide variety of techniques/methods are employed world over for dehydrating foods. The next section presents a review on these methods/techniques.

11.4.4 Drying Techniques and Methods

Several types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of food products including fruit and vegetables. While *sun drying* of fruit crops is still practiced for certain fruit such as prunes, figs, apricots, grapes and dates, *atmospheric dehydration* processes are used for apples, prunes, and several vegetables. *Continuous processes* as tunnel, belt trough, fluidised bed and foam-mat drying are mainly used for vegetables. *Spray drying* is suitable for fruit juice concentrates and vacuum dehydration processes are useful for low moisture / high sugar fruits like peaches, pears and apricots.

Well then we have a wide variety of methods to choose from. Which method to select for which product? This choice is crucial. Factors on which the selection of a particular dryer/ drying method will depends include:

- Form of raw material and its properties;
- Desired physical form and characteristics of dried product;
- Necessary operating conditions;

- Operation costs.

Primarily, there are three basic types of drying process:

- Sun drying and solar drying;
- Atmospheric drying including batch (kiln, tower and cabinet dryers) and continuous (tunnel, belt, belt-trough, fluidised bed, explosion puff, foam-mat, spray, drum and microwave);
- Sub-atmospheric dehydration (vacuum shelf/belt/drum and freeze dryers).

The scope is expanded to include low temperature, low energy process like osmotic dehydration.

As far dryers are concerned, one useful division of dryer types separates them into air convection dryers, drum or roller dryers, and vacuum dryers. Using this breakdown, Table 11.2 indicates the applicability of the more common dryer types to liquid and solid type foods.

Table 11.2 Common dryer types used for liquid and solid foods

Dryer type	Usual food type
Air convection dryers	
Kiln	pieces
cabinet, tray or pan	pieces, purées, liquids
Tunnel	pieces
continuous conveyor belt	purées, liquids
belt trough	pieces
air lift	small pieces, granules
fluidized bed	small pieces, granules
Spray	liquid, purées
Drum or roller dryers	
Atmospheric	purées, liquids
Vacuum	purées, liquids

Vacuum dryers	
vacuum shelf	pieces, purées, liquids
vacuum belt	purées, liquids
freeze dryers	pieces, liquids

Let us learn about the different drying methods now.

Types of Drying Processes for the Dehydration of Foods

You have learnt earlier that there are three basic types of drying processes – sun and solar drying, atmospheric drying, which includes techniques like batch and continuous processes, and sub-atmospheric dehydration. Let us learn about these processes.

Sun and Solar Drying

The use of solar energy to preserve the food items is probably the oldest form of food reservation and is still practiced today for foods such as raisins. Sun and solar drying of fruits and vegetables is a cheap method of preservation because it uses the natural resource/ source of heat i.e. sunlight. The advantages of the process are that the energy is free, renewable and non-polluting. On the other hand, the disadvantages are that it can be very labour intensive, suffers from a lack of control and is prone to deterioration by biochemical reactions or microbiological or insect infestation.

Sun/solar drying method can be used on a commercial scale as well at the village level provided that the climate is hot, relatively dry and free of rainfall during and immediately after the normal harvesting period. The fresh crop should be of good quality and as ripe (mature) as it would need to be if it was going to be used fresh.

Note, poor quality produce cannot be used for natural drying. Different lots at various stages of maturity (ripeness) must NOT be mixed together; this would result in a poor dried product. Some varieties of fruit and vegetables are better for natural drying than other; they must be able to withstand natural drying without their texture becoming tough so that they are not difficult to reconstitute. Some varieties are unsuitable, because they have irregular shape and there is a lot of wastage in trimming and cutting such varieties.

As a general rule plums, grapes, figs, dates are dried as whole fruits without cutting/slicing. Some fruit and vegetables, in particular bananas, apples and potatoes, go brown very quickly when left in the air after peeling or slicing; this discoloration is due to an active enzyme called poly-phenoloxidase. To prevent the slices from going brown they must be kept under water until drying can be started. Salt or sulphite in solution give better protection. However, whichever method is used, further processing should follow as soon as possible after cutting or slicing.

As a food scientist, what should interest us is to learn about the process of sun/solar drying as such. The mechanism of sun and shade drying and the use of specific solar dryers has been described in Box 3 herewith.

Box 3: Sun and solar drying- method

Sun drying

As discussed earlier, the main problems for sun drying are dust, rain and cloudy weather. Therefore, drying areas should be dust-free and whenever there is a threat of a dust storm or rain, the drying trays should be stacked together and placed under cover. In order to produce dust-free and hygienically clean products, fruit and vegetable material should be dried well above ground level so that they are not contaminated by dust, insects, livestock or people. All materials should be dried on trays designed for the purpose; the most common drying trays have wooden frames with a fitted base of nylon mosquito netting. Mesh made of woven grass can also be used. Metal netting must NOT be used because it discolours the product. The trays should be placed on a framework at table height from the ground. This allows the air to circulate freely around the drying material and it also keeps the food product well away from dirt. Ideally the area should be exposed to wind and this speed up drying, but this can only be done if the wind is free of dust. With 80 cm x 50 cm trays, the approximate load for a tray is 3 kg; the material should be spread in even layers. During the first part of the drying period, the material should be stirred and turned over at least once an hour. This will help the material dry faster and more evenly, prevent it sticking together and improve the quality of the finished product. Products for sun drying should be prepared early in the day; this will ensure that the material enjoys the full effect of the sun during the early stages of drying. At night the trays should be stacked in a ventilated room or covered with canvas. Plastic sheets should NEVER be used for covering individual trays during sun drying. Dry or nearly dry products can be blown out of the tray by the wind. However, this can be protected by covering the loaded tray with an empty one; this also gives protection against insects and birds.

Shade drying

Shade drying is carried out for products which can lose their colour and/or turn brown if put in direct sunlight. Products which have naturally vivid colours like herbs, green and red sweet peppers, chilies, green beans and okra give a more attractive end-product when they are dried in the shade. The principles for the shade drying are the same as of sun drying. The material to be dried requires full air circulation. Therefore, shade drying is carried out under a roof or thatch which has open sides; it CANNOT be done either inside conventional buildings with side walls or in compounds sheltered from wind. Under dry conditions when there is a good circulation of air, shade drying takes little more time than is normally required for drying in full sunlight

However, beside this there has been much research to develop simple systems that could be used in developing countries and areas where obtaining other energy sources is limited. The simplest way of carrying out solar drying is to lay the material on the ground in the sun. However this leaves the product open to the spoilage reactions described earlier. Simple structures, such as the solar dryers, can be cheaply built which will enhance the drying conditions. Information on this follows.

Solar Dryers

There are many different designs for solar dryers, these range from simple cabinet dryers, convection dryers, shelf dryers to more complicated semi-artificial dryers that include some form of heat storage device. Typical foods that would be dried using solar dyers include bananas, barley, coffee beans, pepper, peanuts, sweet potato, tea and wheat.

A simple solar dryer can be built and the main parts of the solar dryer being;

1. Drying space, where the material to be dried is placed and where the drying takes place.
2. Collector to convert solar radiation to heat.
3. Auxiliary energy source (optional).
4. Means for keeping drying air in flow. Could be a chimney or a fan.
5. Heat storage unit (optional).
6. Measuring and control equipment (optional).

The drying process can be improved slightly by using some form of heat storage for when sunlight is not incident on the dryer as this means the drying period can be extended using surplus energy and some degree of temperature control may be utilised. Efforts to improve the solar drying process have included the use of forced air circulation and combination with other drying processes, such as conventional drying processes and osmotic drying.

Check Your Progress Exercise 2

1. Define the following:

(a) Canning

(b) Dehydration

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2. List the sequence of canning operations.

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3. Give a few advantages of the canned foods.

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4. What is the main principle behind drying?

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5. Mention a few factors that affect drying rate and total drying time.

So far we learnt about solar/sun drying method. Now have a look at the atmospheric and sub-atmospheric drying methods. A brief review of the different methods follows.

Tray and Tunnel Dryers: Tray and tunnel dryers are widely used in the food industry. In both cases the material being dried is supported on multiple trays, with the hot air being directed at high speed between and across the surfaces. Tray dryers operate in batch mode. However, two or more of the larger versions of this dryer may be linked to provide semi-continuous operation.

Tunnel dryers provide a natural extension to this concept and are continuous. The tunnel dehydrator is by far one of the most flexible systems, which is in commercial use. In its simplest form it consists of a rectangular tunnel which will accommodate trucks containing the trays on which the product to be dried is uniformly spread.

Conveyor (or Band) Dryers: In the conveyor (or band) dryer, the product is distributed on a moving belt, typically of a perforated plate, that passes through a tunnel like structure in which vertical airflow is strictly controlled. With the exception of transfer operations (or occasional deliberate stirring of the bed), the individual particles remain fixed in position with respect to one another.

This type of drying system is very similar to the tunnel system except that the material is conveyed through the hot air system on a continuous moving belt. The system has the advantage that the high cost of handling products both before and after drying using trays is substantially reduced. This drying system is used for downstream operations such as cereal puffing.

Rotary Dryers: Rotary dryers are widely used to dry relatively large throughputs of granular products and by products in a number of industries, including the food industry. Rotary dryers are characterised by a slowly rotating cylindrical drum, which is normally inclined at a small angle (0 - 5°) to the horizontal. The product to be driedis introduced into the upper end and dried product is withdrawn at the lower end. There are a number of different types of rotary dryer; one of the most common is the cascading rotary dryer. Typical food products dried in rotary dryers include fish scraps, wheat residues, cocoa beans, nuts, cooked cereals, flour, sugar and spent grains.

Fluidized, Torbed and Agitated Bed Dryers

Fluidization occurs when a flow of fluid upwards through a bed of particles (ranging from fine powders to particulate foods such as diced carrots) reaches sufficient velocity to support the particles without carrying them away in the fluid stream. The bed of particles then assumes the characteristics of a boiling liquid, hence the term fluidization. The fluid responsible for fluidization may be a gas or air the choice of which will confer different properties on the fluidizing system.

Fluidized bed dryers can be used for either of the following situations:

a) Finish or final drying of products partially dried by other techniques; for example, blueberries dried osmotically are then dried at 170°C for 4 minutes in a high temperature fluidized bed.

b) Drying foods completely - examples of this include the drying of grains, soybeans, peas, beans and vegetables.

The complete drying of foods in fluidized beds may be carried out either by the use of a "high temperature short time" process or by a more gradual process at a lower temperature. Delicate fruits such as blueberries are dried by the HTST process (170°C for 8 minutes), whereas oil seeds are dried over a longer period of time (55-65°C for 4 hours). This longer, cooler process is required so that the quality of the oil and the germination characteristics of the grain are not affected.

Torbed Dryer, on the other hand, is a variation of the fluidized bed dryer. This is designed for use with particulate foods. Torbed dryers are used to dry hazelnuts, carrots, mushrooms, beef dices and shrimps. Grated cheese can also be dried in fluidized beds.

The distinction between *agitated bed* and *fluidized bed drier* is a narrow one, since in each case an upward velocity of air sufficient to support the food particles is applied. In the case of the former the bed is less vigorously stirred than in the latter. It is necessary with driers of this type to decrease the air velocity as the particle dries in order to prevent the particles being lost from the system. The final drying is accomplished using bins.

The fluidized bed principle represents an important advance that can be used for a wide range of particulate materials. Apart form the commercial drying of peas, beans and diced vegetables it is also used for drying potato granules, onion flakes and fruit pieces.

Explosion puffing: Explosion puffing has been recognized as one of the most significant developments in dehydration technology. In explosion puffing, partially dehydrated pieces from a preliminary stage drying are heated in a closed rotating cylindrical container known as a 'gun' until the internal pressure has reached a predetermined value. When this point has been reached the gun is discharged instantly to atmosphere. During this process a certain amount of water is vaporized but, more important, the explosive or flashing conditions cause a highly porous network of capillaries to be developed within the particles. This porosity enables the final dehydration to be achieved much more rapidly (approximately twice) than would have been the case with conventionally dried products. It also bestows on the product the ability to reconstitute extremely rapidly.

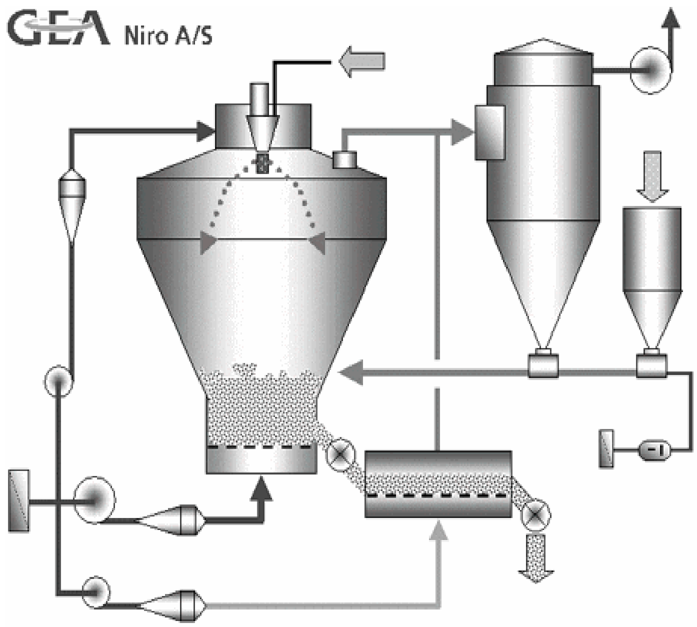
Vacuum Puff Drying: The vacuum puff process has been developed for drying liquids under vacuum. The development of processes for drying liquids under vacuum came from the observations made on the freeze drying of orange juice concentrate. The rate of drying of the product in the liquid state was double that in the frozen state (freeze drying) and the dried product had a highly porous structure, which exhibited good rehydration properties. This was due to the fact that under vacuum conditions the liquid tends to foam and produce a film structure, which dries to give a highly porous solid.

Foam Mat Drying: This process is a development of the vacuum puffing but, instead of employing a vacuum to foam the material, it is initially foamed by suitable agents and then subjected to drying under atmospheric pressure. The equipment required for this is similar to the continuous band drier described previously, without the vacuum facilities.

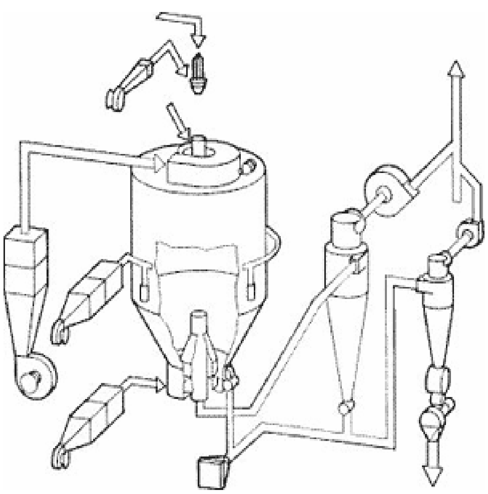
Microflake-T dehydration: This technique involves the drying of a continuous sheet of foam 20 mm thick on a continuous stainless steel belt. The later is heated from below by steam and above by a high velocity air stream and drying times are reported to be about one tenth of the standard process.

Spray Drying: Spray drying is a unique drying process since it involves both particle formation and drying. It is most suitable for drying of liquid foods such as milk, fruit juices etc. The feed is converted into small droplet with the help of a nozzle or atomizer and then droplets are dried in a drying chamber when they come in contact with hot air. The product is separated from hot air by a cyclone separator and collected. The characteristics of the resultant powder can be controlled and powder properties can be maintained constant throughout a continuous operation. With the designs of spray dryers available, it is possible to select a dryer layout to produce either fine- or coarse-particle powders, agglomerates or granulates.

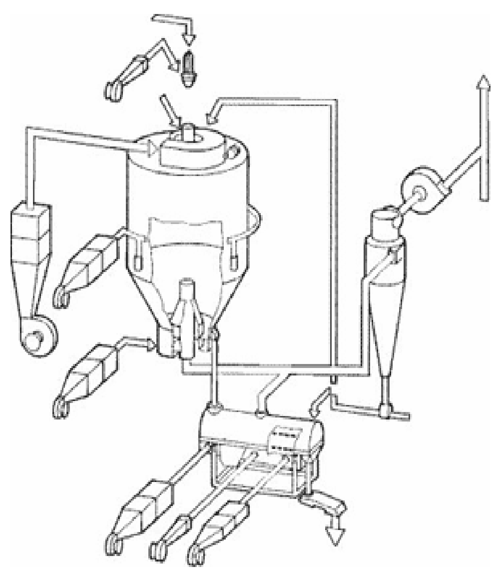
Spray drying involves the atomisation of feed into a spray, and contact between spray and drying medium resulting in moisture evaporation. The drying of the spray continues until the desired moisture content in the dried particles is achieved, and the product is recovered from the air. There are various types of spray dryers such as two stage dryers, three stage dryers, multi stage dryers and compact spray dryers. Figure 11.1 illustrates the different spray dryers.



Multi stage spray dryer



Two stage spray dryer



Compact spray dryer

Figure 11.1: Different types of spray dryers

Foam Spray Drying: This is an extension of spray drying and involves the use of gases dissolved under pressure prior to spraying. The main advantage is that the density of the product is reduced by half and the dried particles are hollow spheres surrounded by thick walls of dried material. The foam process produces particles having many internal spaces and relatively thin wall.

Roller Drying (Drum drying): One of the important techniques for drying liquid food products is the roller drier. Like spray drying, roller drying can only be used for liquid products, which can either have a low viscosity or be highly viscous to paste like. Roller dryer is also called drum drying. The metal rollers are heated from inside with condensing steam and the product dries as a thin film by contact with the cylinder surface. While spray drying is done purely by vaporisation, evaporation is the main process in roller drying since the saturated vapour pressure is equal to the atmospheric pressure. The product to be dried is spread as a thin film on to the surface of the hot drum and after one revolution is scraped off by a knife, in the form of flakes, scales or powder. A large part of the roller dried whole milk powder is destined for chocolate manufacture. Roller drying is extensively used for the manufacture of 'instant' potato products, potato flakes, and also for all liquid food products including infant foods, fruit products, eggs, milk and beverages.

Freeze Drying: The Techniques of freeze-drying have been developed over the past half-century for the purpose of preserving certain biological materials, which are costly to produce, and which are highly unstable. Perhaps its most notable successes have been in the preservation of human plasma for transfusion purposes and in the preservation of the early samples of penicillin during the war. Today it has numerous applications in the pharmaceutical industry, but it falls far short of requirements for the food industry. The cost of the process is also still too high to make it a practical proportion for many of the cheaper foods.

In this method of removal of water the product is frozen and the temperature maintained below the triple point of the constituent aqueous solutions so that the water vapour can be sublimed from the frozen state. There is, therefore, a direct transfer from solid to vapour without the ice melting and passing through the liquid phase. The process is carried out under high vacuum to provide a high vapour diffusion potential and is accelerated by supplying heat in some convenient form, either radiant, conductive or from microwaves. It is generally considered that as a means of dehydration. It produces a dried product of the highest quality and therefore is potentially an extremely attractive method.

The major aspects of the mechanism of freeze drying are:

(a) The removal of vapour from the subliming ice front within the material,
(b) The removal of vapour from between the food particles,
(c) The supply of heat to the food particles,
(d) The supply of heat to the ice within the food particles

The conventional freeze drying unit consists of a vacuum chamber into which trays of the material to be dried can be placed, and a source for supplying heat to the material so that the sublimation process can be accelerated. The usual method is to arrange the trays on or between the heated plates, which are either electrically heated or internally heated with steam. The vacuum is produced either with a mechanical pump, suitable steam ejectors, or refrigerated condensers.

Other Types of Drying: There are many other dryer types available, such as;

- Osmotic Drying
- Impingement Drying
- Microwave and Dielectric Drying
- Superheated Steam Drying
- Electrohydrodynamic Drying

So far we have learnt about the dehydration process and the different methods which can be used and are in use in the food industry for dehydration of foods. Next, we shall look at yet another form of preservation method i.e. concentration.

11.5 PRESERVATION BY CONCENTRATION

First what do we mean by concentration. Concentration is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It is thus a thermal separation or thermal evaporation process.

But, why do we need to concentrate foods. Foods are concentrated for many of the same reasons that they are dehydrated; concentration can be a form of preservation but this is true only for some foods. Concentration reduces weight and volume and results in immediate economic advantages. Nearly all liquid foods which are dehydrated, need to be concentrated before they are dried. This is because in the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment. Further, increased viscosity from concentration often is needed to prevent liquids from running off drying surfaces or to facilitate foaming or puffing.

Foods are also concentrated because the concentrated forms have become desirable components of diet in their own right. Thus, fruit juices plus sugar with concentration becomes jelly. The more common concentrated fruit and vegetable products include items as fruit and vegetable juices and nectars, jams and jellies, tomato paste, many types of fruit purées used by bakers, candy makers and other food manufacturers.

The level of water in virtually all concentrated foods is in itself more than enough to permit microbial growth. Yet while many concentrated foods such as non-acid fruit and vegetable purées may quickly undergo microbial spoilage unless additionally processed, such items as sugar syrups, jellies and jams are relatively "immune" to spoilage; the difference of course is in what is dissolved in the remaining water and what osmotic concentration is reached.

Removal of water by concentration also increases the level of food acids in solution (particularly significant in concentrated fruit juices). While the preservation effects of food concentration are important, the main reason of most food concentration is to reduce food weight and bulk. Tomato pulp, which is ground tomato devoid of the skins and seeds, has a solid content of only 6 % and so a 3.78 liter can would contain only 230 g of tomato solids. Concentrated to 32% solids, the same can would contain 1.38 kg of tomato solids or six times the value of product. For a manufacturer needing tomato solids such as producer of soups, canned spaghetti or frozen pizza the saving from concentration are enormous.

So you realize how concentration as a method of preservation is useful in the food industry. Further, we would also like to know how the process of concentration is carried out. A brief discussion on the different methods of concentration which are used at the home or industrial level follows.

11.5.1 Methods of concentration

We define the concentration process as one that starts with a liquid product and ends up with a more concentrated, but still liquid and still pumpable concentrate as the main product from the process.

In most cases, it is essential that the product be subject to minimal thermal degradation during the concentration process, requiring that temperature and time exposure must be minimized. This and other requirements brought on by the physical characteristics of the processed product have resulted in the development of a large range of different evaporator types. An evaporator, as you may have realized, is generally used to concentrate the liquid food products. Some of the common evaporators frequently used in food industry include falling film evaporators, rising film evaporators, forced circulation evaporators and plate evaporator. We shall not go into the details of the functioning of these evaporators, but you should know that in almost all evaporators the heating medium is steam, which heats a product on the other side of a heat transfer surface.

Here, however, we would like to bring to your notice some of the simple techniques one can use for evaporation during concentration process. These include:

a. *Solar concentration:* As in food dehydration, one of the simplest methods of evaporating water is with solar energy. A typical example of this method is production at farm level in developing countries of fruit pastes/leathers (such as apricot or plum pastes).
b. *Open Kettles:* Some foods can be satisfactorily concentrated in open kettles that are heated by steam. This is the case for jellies and jams, tomato juices and purées and for certain types of soups. High temperatures and long concentration times should be avoided in order to reduce or eliminate damage. It is also necessary to avoid thickening and burn-on of product to the kettle wall as these gradually lower the efficiency of heat transfer and slow the concentration process. However, when the process is under control, this type of evaporation is still highly recommended for small scale operations in developing countries. It is a quite widely used system, mainly for jellies, jams and marmalades.
c. *Vacuum evaporators:* It is common to construct several vacuumised vessels in series so that the product moves from one vacuum chamber to the next and thereby becomes progressively more concentrated in stages. With such an arrangement the successive stages are maintained at progressively higher degrees of vacuum, and the hot water vapour produced by 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 made. Such system is called a multiple effect vacuum evaporator. It is a widely used system for concentrated tomato paste.

d. *Freeze Concentration:* This process has been known for many years and has been applied commercially to orange juice. However, high processing costs due largely to losses of juice occlude [unclear] to the ice crystals, have limited the number of installations to date.

Equipped with the knowledge of how to concentrating foods, with or without evaporators, let us next learn about the applications of evaporators in food and dairy Industry, where concentration is carried out. This is highlighted in Table 11.3.

Table 11.3: Some representative applications of evaporators in food and dairy industry, where concentration is carried out

Milk products	**Fruit juices**
Whole & skim milk	Orange & other citrus juices
Condensed milk & Cream	Apple & other pomaceous juices
Buttermilk	Mixed juices, Tropical fruit juices Coconut milk
Milk permeate & proteins	
Sweet whey & sour whey	**Other applications**
Whey permeate & protein	Baby food
Lactose solutions	Egg white
Vegetable juices	Fermentation liquids
Tomato juice	**Hydrolyzates**
Carrot juice	Hydrolyzed whey
Beetroot juice	Hydrolyzed milk
Grass juice	Soup seasoning
Extracts	Protein hydrolyzate
Meat & bone extract	**Organic Natural Products**
Coffee & tea extract	Fermentation broths
Hop extract	Glue & gelatine
Malt extract	Emulsions
Yeast extract	Extracts

Pectin	Stick water
High-protein juices	Organic effluents
Soya whey	Blood
Yeast extract	
Fodder yeast	

Finally before we end our discussion on concentration, let us look at the effect of concentration on physical/nutritional quality of food.

11.5.2 Changes due to Concentration Process

Obviously concentration that exposes food to 100°C or higher temperatures for prolonged periods can cause major changes in organoleptic and nutritional properties. Cooking of foods and darkening of colour are two of the more common heat induced results, which must be kept under control during a well designed process with an efficient evaporator which is still "safe".

Microbial destruction is another type of change that may occur during concentration and will be largely dependent upon temperature. Concentration at a temperature of 100 °C or slightly above will kill many microorganisms but cannot be depended on to destroy bacterial spores. When the food contains acid, such as fruit juices, the extent of inactivation will be greater but again sterility is unlikely. On the other hand, when concentration is done under vacuum many bacterial types not only survive the low temperatures but also multiply in the concentrating equipment. It is therefore necessary to stop frequently and sanitize low temperature evaporators and where sterile concentrated foods are required, to resort to an additional preservation treatment.

Check Your Progress Exercise 3

1. What do you understand by the term 'concentration'?

    ----

2. Give a few reasons why do we need to concentrate foods.

    ----

3. List some of the simple techniques used for evaporation during the concentration process.

11.6 LET US SUM UP

In this unit, you studied the various methods of food processing. You learnt that food being most vital for the survival of human beings must be processed using scientific techniques. In this context, you learnt in a great detail about thermal processing i.e., cooking, blanching, pasteurization, sterilization and canning; dehydration and various drying techniques.

Another aspect which was considered in this unit was the preservation by means of concentration. In this, the main focus was on the various methods of concentration and the changes that occur in food as a result of concentration.

11.7 GLOSSARY

Bound water : Water which is in some way bound to the food so that it exerts a vapour pressure less than that of pure water.

Concentration : An operation used to remove a liquid from a solution, suspension or emulsion by boiling off some of the liquid.

Conduction : The transfer of energy through a medium without bulk movement of the medium itself.

Convection : A process of transfer or transmission, as of heat and electricity, by means of circulation of currents in liquids or gases resulting from changes of temperature and other causes.

Dry bulb temperature : Air temperature as indicated by an ordinary thermometer.

Food Preservation : A process by which certain foods are prevented from getting spoilt for a long period of time. It preserves the colour, taste and nutritive value of the food.

Food Processing : Conversion of raw materials and ingredients into a consumer food product.

Free Water : Water which is bound by such minute forces, that its vapour pressure is equal to the vapour pressure of pure water.

Heat of vaporization : Heat required to overcome the molecular forces of attraction between the particles of a liquid, and bring them to the vapour state, where such attractions are minimal.

Organoleptic properties : Relating to qualities (as taste, colour, odour, and feel of a substance that stimulate the sense organs.

Relative humidity : Ratio of the quantity of water vapour present in the air to the highest amount possible at a given temperature, expressed as a percentage.

Sanitize : To make less offensive or more acceptable by killing all living including bacteria and algae.

Still retorts : Cylindrical glass containers used in canning plants for heating foods.

Latent heat of Vaporization : The amount of heat energy required from the environment to change the state of a liquid to a gas.

Water activity : Ratio of vapour pressure of a food to the vapour pressure of pure water.

11.8 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

(i) Preparation of the products fit for consumption and destruction or inactivation of pathogens found in food.

(ii) Thermal processing

(iii) Any two of the following: Destruction/reduction of microorganisms; Inactivation of undesirable enzymes; Destruction of hazardous toxins; Alteration of colour, flavor, and texture; Improved digestibility.

(iv) Thermopenetration

(v) Q value

2. The functions of blanching are listed as (any five):

- Inactivate most enzymes
- Cleaning action
- Removes substances in some products
- Activates some enzymes
- Removes undesirable odors/ flavours
- Softens fibrous material and decreases volume
- Expels air and respiratory gases
- Preheating of product prior to canning

3. A few benefits of blanching are:

- cleaning the material and reduce the amount of microorganisms present on surface
- Preserving natural colour in dried products
- Shortening the soaking/ cooking time during reconstitution

4. Pasteurization is a mild heat treatment to kill a part of the microorganisms present in food. There are two categories of pasteurization. These are:

a) LTLT: In this, the pasteurization time is in the order of minutes and related to the temperature used. To typical temperature/time combinations are used: 63-65^{o}C over 30 minutes or 75^{o}C over 8-10 minutes.

b) Rapid, high or flash Pasteurization: It is characterized by a pasteurization time in the order of seconds and temperatures of about 85^{o}C to 90^{o}C or more, depending on the holding time. Typical temperature/time combinations may be: 88^{o}C for 1 minute; 100^{o}C for 12 seconds; and 121^{o}C for 2 seconds. The 121^{o}C for 2 seconds treatment gives the best quality products in respect of flavour and vitamin retention.

5. Thermal conditions required to produce commercial sterility are: nature of the food, storage conditions during post processing; heat transfer characteristics of food, container and heating medium; and initial load or quantity or organisms present.

Check Your Progress Exercise 2

1.

a) Canning is a process for conservation of foods and its nutritional qualities for along duration at ambient temperature, obtained by a process associating a heat treatment and a water proof packing.

b) Dehydration is a technique that involves the application of heat to vapourise after its separation from the fruit/vegetable tissues. It is a combined/simultaneous transfer operation for which the energy must be supplied.

2. The sequence of canning operations are as: food preparation, filling of can/receptacle, vaccum production, thermal processing, cooling, labeling and packing.

3. The advantages of canned foods are safe and hygienic and high nutritional value, economical, availability in a wide assortment and have utility value and can be kept for a long period

4. The main purpose of drying is to extend the shelf-life of foods by a reduction in water activity (a_w). This will inhibit microbial growth, however, the processing temperature will not normally be sufficient to cause inactivation, thus care is needed to be taken with the product on subsequent rehydration.

5. A few factors that affect the drying rate and total drying time are:

- Properties of the products
- Geometrical arrangement of the products
- Physical properties of drying medium/environment
- Characteristics of drying equipment

Check Your Progress Exercise 3

1. Concentration is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid.

2. The reasons to concentrate foods are:

a) it is a form of preservation

b) it reduces weight and volume and results in immediate economic advantages.

c) Concentrated forms have become desirable components of the diet.

3. The simple techniques used for evaporation during the concentration process are solar concentration, open kettles, vaccum evaporation and freeze concentration.

UNIT 12 METHODS OF FOOD PROCESSING – 2

Structure

12.1 INTRODUCTION

In the previous unit, we began our discussion on the methods of food processing by covering the two major methods- thermal processing and dehydration. Here, in this unit, we shall focus on the other food processing methods which include freezing, microwave processing, irradiation, fermentation, deep fat frying and use of salt, sugar and chemicals as preservatives. What is freezing and the different types of freezing systems available for foods? How do microwaves help to process and preserve food? How can simple home-based methods such as deep fat frying and use of salt, sugar and chemicals act as a preservative technique/measure. These are a few issues discussed in this unit.

Objectives

After studying this unit you will be able to:

- understand the different food processing techniques
- discuss freezing systems in detail
- describe microwave processing, its applications and advantages

- enumerate the different fermented products and their method of preparation involving use of various microorganisms and
- explain the use of salt, sugar and chemicals as preservatives.

12.2 FREEZING

Freezing, as a method, is the easiest, most convenient and least time-consuming way of preserving foods. Freezing does not sterilize foods or destroy the organisms that cause spoilage. How then does it preserve foods? Well, the extreme cold simply slows the growth of microorganisms and the chemical changes that affect quality or cause spoilage. You already know that all microbial and biochemical activities are temperature dependant and slow down as the temperature is reduced. As a rule of thumb, for every 10°C temperature change, the rate of reaction changes by a factor of 2 to 3.

Further, freezing helps to preserve food by its action on enzymes. Enzymes, as you already know are complex proteins, present in all living tissue, that help organisms ripen and mature. During freezing, enzyme action is slowed but not stopped. If not inactivated, these enzymes can cause color and flavor changes and loss of nutrients during freezer storage.

We are all familiar with chilling and refrigerated storage. At home or at the industry level, refrigerated storage of food is generally practiced. In the unit operation of chilling, the temperature of a food is reduced generally to between –1°C and 7 °C and thus subsequent storage at refrigerated temperature extends the shelf life of both the fresh and processed foods. It is also used as an adjunct process to extend the storage life of mildly processed (e.g. pasteurized, fermented and irradiated) and low-acid foods. In the United States, refrigerated storage of food is mandated by regulations at temperatures at or below 7.2°C. Such foods are also marketed under refrigeration and labeled as 'needing refrigeration'. Commercially sterilized and processed foods that may become contaminated after opening should also be labeled for refrigerated storage.

Chilling and refrigerated storage prevents the growth of bacteria, particularly the thermophiles (organisms that grow at high temperature) and mesophiles (organisms that grow at medium temperature). Psychrophiles (organisms that grow at low temperatures), however, can and do cause food spoilage during low temperatures storage, but there are some psychrophillic pathogens, as listed in Table 12.1, that need attention.

Table 12.1 Psychrophilic foodborne pathogenic bacterial species

Identified species	Foods Associated
Aeromonas hydrophila	Sea foods
Escherichia coli *Pseudomonas species*	Milk and milk products Meat and meat products Water habitats
Bacillus cereus	Cereal and cereal products Milk and milk products Meat and meat products
Listeria monocytogenes *Yersinia enterocolitica* *Campylobacter jejuni*	Milk and milk products Meat and meat products

Freezing, you would realize, is the most convenient way of preserving foods. Different types of freezing systems are available for foods. Let's get to learn about these systems.

12.2.1 Freezing Systems

Different types of freezing systems are available for foods. No single freezing system can satisfy all freezing needs, because of the wide variety of food products and process characteristics. Can you mention a few of these characteristics which may influence the choice for a particular system? The selection criteria of a freezing system will depend on the type of the product, reliable and economic operation, easy cleanability and hygienic design, and desired product quality.

Although all commercial freezing processes are operated at atmospheric conditions, there are potential applications of high-pressure assistant freezing and thawing of foods. The pressure – induced freezing point and melting point depression enables the sample to be supercooled to low temperature (e.g., - 22° C at 207.5 M pa) resulting in rapid and uniform nucleation and growth of ice crystals on release of pressure.

The different freezing systems are summarized herewith:

A. Freezing by Contact with a Cooled Solid: Plate Freezing

In this method, the product is sandwiched between metal plates and pressure is usually applied for good contact. Plate freezers are only suitable for regular-shaped materials or blocks. When the product has been frozen, hot liquid is circulated to break the ice seal and defrost. Spacers are used between the plates during freezing to prevent crushing or bulging of the package.

B. Freezing by Contact with a Cooled Liquid: Immersion Freezing

In this method, the food is immersed in low-temperature brine to achieve fast temperature reduction through direct heat exchange. The fluids usually used are salt solutions (sodium chloride), sugar solutions, glycol and glycerol solutions, and alcohol solutions. In order to ensure that the food does not come into contact with liquid refrigerants, flexible membranes are used to enclose the food completely, while allowing rapid heat transfer.

C. Freezing by Contact with a Cooled Gas

Different methods are available for freezing by contact with cooled gas. These include:

i) Cabinet Freezing: This method involves circulation of cold air in a cabinet where the product is placed in a tray. The moisture pick-up from the product may deposit on the cooling coils as frost, which acts as an insulation.

ii) Air–Blast Freezing: The method employs the use of high velocity cold air to reduce the temperature of the food. Air velocities between 2.5 and 5 m/s give the most economical freezing. Lower air velocities result in slow product freezing and higher velocities increase unit freezing costs considerable. This method can be further divided into fluidized bed freezing, belt freezing, and tunnel freezing, depending on how the air interacts with the product. Now we will discuss each of these methods:

- *Fluidized Bed Freezing:* A fluidized bed freezer consists of a bed with a perforated bottom through which refrigerated air is blown vertically upwards. The air velocity must be greater than the fluidization velocity. This freezing method is suitable for small particulate food bodies of fairly uniform size, e.g., peas, diced carrots, corns and berry fruits. The high degree of fluidization improves the heat transfer rate and results in good use of floor space.

- *Belt Freezing:* The first mechanized air-blast freezers consisted of a wire mesh belt conveyor in a blast room for continuous product flow. Uniform product distribution over the entire belt is required to achieve uniform product contact and effective freezing. Controlled vertical airflow forces cold air up through the product layer, thereby creating good contact with the product particles and increasing the efficiency. The principal current design is the two – stage belt freezer. Temperatures used are usually – 10 to 4 °C in the pre-cool section and – 32 to – 40° C in the freezer section.

- *Tunnel Freezing:* In this process, the products are placed in trays or racks in a long tunnel and cool air is circulated over the product.

iii) Cryogenic Freezing: Cryogenic Freezing, as you would realize, is one of the fast, flexible and cheap method of freezing. In this, the liquefied gases are placed in direct contact with the foods. Food is exposed to an atmosphere below – 60°C through direct contact with liquid nitrogen or liquid carbon dioxide or their vapor. This is a very fast method of freezing, thus adequate control is necessary for achieving quality products. It also provides flexibility by being compatible with various types of food products and having a low capital cost. The rapid formation of small ice crystals greatly reduces the damage caused by cell rupture, preserving color, texture, flavor and nutritional value. The rapid freezing also reduces the evaporative weight loss from the products, provides high product throughput and has low floor space requirements.

The cryo-mechanical technique utilizes a cryogenic gas to create a frozen crust on a fluid product, after which the product may be conveyed to a conventional mechanical freezer. The advantages of liquid nitrogen are that it is colorless, odorless and is chemically inert and boils at 195.8°C. It is usually used for high-value products due to the high capital cost for gas compression. The product can be exposed to a cryogenic medium in three ways:

(a) The cryogenic liquid is directly sprayed on the product in a tunnel freezer.
(b) The cryogenic liquid is vaporized and blown over the food in a spiral freezer or batch freezer.
(c) The product is immersed in the cryogenic liquid in an immersion freezer.

With this, we come to an end on our discussion on freezing as a method of preservation. Let us now attempt the exercises given in Check your progress exercise 1 and see how much we have grasped the knowledge on this subject.

Check Your Progress Exercise 1

1. Fill in the blanks:

(i) The freezing process involves -------------------------------------- and ----------------------- .

(ii) For every 10^{o}C temperature change, the rate of reaction changes by a factor of ------------

(iii) The temperature range which extends the shelf-life of fresh and processed foods is --------

(iv) ------------ organisms cause food spoilage during low temperatures storage.

(v) The selection criteria of a freezing method are ------------------------, ------------------------ -------------------------------- and --------------------------------------- .

2. Explain how the process of freezing helps in preservation of foods.

----

3. What are the different methods of freezing?

----

4. A single freezing system is enough to satisfy all freezing needs. Why?

----

5. Explain, very briefly, what is meant by 'Cryogenic freezing'? Also, give its advantages over other freezing methods.

12.3 MICROWAVE PROCESSING

You would have realized that usage of microwave, as one of the techniques of food processing, has tremendously increased in recent times. Can you suggest why? Here, in this section, we would look into various aspects of microwave processing which make it a choice of food technologists as well as households.

Food industry, in the recent years, has witnessed the emergence of microwave oven as a substitute for thermal oven for a number of food processes and products. Microwave processing results in an excellent retention of nutritional and sensory value, besides having other advantages namely savings in energy, cost, time, etc. Though it had a limited applicability in the past, microwave processing is a boon to the food industry and it has a tremendous potential, if explored properly. The modern life, as well as, the increasing number of working industries requires simplified routines and standardization of foods with lesser preparation time and convenience in usage. The increasing consumer demands for foods, which offer more convenience in the use and savings in preparation, make the food processor to go for microwave oven as an alternative to the conventional thermal ovens. The speed with which the heating takes place in the microwave oven, contributes to the most to its rapid growth and practically, it has become a household item today.

Let us then understand what are microwave radiation, how they heat and their advantages, in the following sections.

12.3.1 A look at Microwave Processing

The first thing which comes to our mind while on the topic of microwave processing is what microwaves are? Microwaves are basically *electromagnetic waves that have a frequency between 300 MHz and 300 GHz*. These two frequencies correspond to wavelengths of 1 m and 1 mm, respectively. All domestic microwave ovens and laboratory microwave processors operate at 2.45 GHz (corresponding to a wavelength of 12.2 cm, or just over 4-3/4"). Microwave energy is not suited for every application. But, in those applications where it fits, it can provide many process benefits. Let us next look at the microwave process.

The most common way to heat a product is from the outside in - heat penetrates, molecule by molecule, into the interior of the product. As a rule, when a product's moisture content is high (50 to 95%), conventional heating methods are the most economical technology. But, heating products with low moisture content (below 20%) is difficult. Microwave energy has the unique ability to heat certain molecules while not heating others. Because of this unique characteristic, microwave energy often is employed to draw out the last few percent of moisture in a range of products. This ability can be especially helpful in applications such as drying, where the residual moisture can have damaging results.

Microwaves pass through a product like light passes through glass. Materials without a dipolar electrical charge (some plastics, for example) do not react with the waves. However, asymmetrically charged materials - especially water, which is by far the most common material with a dipolar charge, react to the microwaves by trying to align themselves, to the electromagnetic charge. Because of the microwaves' electromagnetic field reverses as much as a couple of billions times per second, the dipolar molecules continually change alignment, producing energy that is converted into heat. The amount of energy converted is dependent on the electric field strength, the microwave frequency and the dielectric properties of the food. In effect, the water molecules heat themselves until the product becomes so hot that the water present in the product evaporates. Combination curing with microwave is better than any other heating methods. Microwaves can remove the last few percent of moisture from a product's interior and this process can be completed rapidly without overheating the already dried material. In fact, drying materials to levels as low as 3% moisture content, within a relatively short time is possible with microwaves.

In many applications where microwave technology is considered, a combination of microwave and conventional heating methods often is the best. Conductive or convective processing steps can be used before, during and after the microwave stage. The choice depends on product and the process. If microwaves are used first, the result is more effective for initial heating. If conventional and microwave heating are applied at the same time, there is a synergistic effect:

Microwave heat pumps the product's moisture to the surface, where it is evaporated by convective airflow - producing more effective drying than convection-only systems.

The heating of materials by microwave is affected by a number of properties of the equipment and the material being heated. The important factors influencing the heating patterns are:

- Microwave frequency
- Microwave power and speed of heating
- Mass of the material
- Moisture content of the product
- Product density
- Product temperature

A discussion on these factors follows:

- *Frequency:* There are two available frequencies for microwave heating - 915 and 2,450 MHz; the frequency affects the depth of penetration into a material. Generally very large materials such as 30 kg blocks of frozen fish to be tempered might be better processed at 915 MHz, while the cooking of individual sausage patties favor 2,450 MHz.
- *Microwave power and speed of heating:* Most industrial systems operate at microwave power outputs ranging from 5 to 100 kW with some extending beyond these limits. The higher the power output, the faster the heating for a given mass. Varying the power output usually controls the speed of microwave heating. Speed is usually the most attractive feature of microwave heating. This is a double-edged sword, however, since it is possible to heat rapidly cooking, baking and other food processes are complex physiochemical systems requiring the input of heat to initiate and accelerate reactions. However, these reactions must occur in a proper order and be given proper time to occur. One of the best examples of critical nature of the rate of heat input is 'baking'. Another problem that can arise from excess speed of heating is non-uniform temperature distribution. This occurs because the heating may be so fast as to prevent the effectiveness of thermal conductivity in transferring the heat to the cooler portions.
- *Mass:* There are two considerations - the total mass being heated at one time and the mass of an individual piece; the latter will be treated below under physical geometry and density. As far as the total mass is concerned, there is a direct relationship between the

mass and the amount of microwave power, which must be applied to achieve the desired heating. Microwave systems can be built to accommodate 25, 250 or 2500 kg or any amount of material per hour. When total mass is small, this might best be done in a batch oven, where as a larger throughput, would often be better done in a conveyorised system. Such systems have an added advantage of providing greater heating uniformity by moving the product though the microwave field.

- *Moisture content:* Water content is the major influencing factor that indicates how well materials, particularly foods, absorb microwave energy. Usually, the more water present, the higher the dielectric loss factor and hence the better heating. However, the lower moisture product may also heat well, since its specific heat decreases. As the product becomes dryer, very often wetter areas absorb the microwave energy preferentially and moisture-leveling effect is seen. This effect is very useful in drying operations.
- *Density:* The density of a product has an effect upon its dielectric constant. The dielectric constant of air is 1.0 and air is for all practical purposes, completely transparent at the industrial heating frequencies, thus air inclusion will reduce materials' dielectric constant. Hence as material's density increases so does its dielectric constant, almost linearly. Very porous material, such as bread dough, because of air inclusion are good insulators and become better insulators as they are baked and their density decreases. Thus, heat transfer into these materials is very difficult and slow, except in microwave heating, where microwaves penetrates deeply and are able to bake the bread in one third of conventional time or less.
- *Temperature:* The temperature of a material plays a role in microwave heating in several ways:

1) The dielectric loss may increase or decrease with temperature, depending upon the material since temperatures and moisture levels change during heating, they may have a profound effect upon the dielectric properties.
2) Freezing has a major effect upon a material's heating ability, because of the vast difference in dielectric properties of ice and water. Water is highly absorptive and heats faster, ice is highly transparent and doesn't heat. This is why tempering, the rising of the temperature of frozen materials to just below the thawing point, is done rather than thawing.

3) The starting temperature of the food products being heated by microwaves should either be controlled or known, so the microwave power can be adjusted to obtain uniform final temperatures. In other words, if a microwave system is set to rise the temperature of the material from 200 to 800°C, but the starting temperature is only 150°C, it will rise the temperature to only 750°C unless the microwave power incidence in to the system is increased.
4) Higher core heating is achieved at 915 MHz and surface heating at 2450 MHz.
5) Edge and corner overheating: Irregular shaped products heat non-uniformly. Chicken heats more near bone than in the meat.
6) Spot heating in heterogeneous products: Frozen foods heat non-uniformly. Microwave penetration is greater in ice than in water but absorption in water is higher.

With the basic understanding on microwave heating, can you now enumerate the basic advantages of microwave processing? Try listing them down and tally your responses with the advantages enumerated herewith.

12.3.2 Advantages of microwave heating

Compounds with high dielectric constant (e.g. water and ethanol) tend to heat readily under microwave heating, while less polar materials with no net dipole moment (e.g. CO_2) and highly ordered materials (such as ice) are poor microwave absorbers. This circumstance arises because energy transfer is not primarily by conduction or convection, as with conventional heating, but by dielectric loss. The difference in mechanism of heating offers the following advantages for microwave assisted processing:

1) Rapid response: The sample absorbs the energy directly, so the time required for the heating up reaction mixtures are short, allowing selectivity in some reactions and enabling operators to efficiently manage their work.
2) Because the reaction mixture heats directly, the chamber does not heat up substantially. When the power is turned off, heat input ceases immediately, an important safety consideration.
3) There are minimal temperature gradients across the reaction vessel, so the temperature of the material on the wall is not significantly different from that in the body of the reaction mixture

4) Both continuous and batch microwave reactors can allow unstable products to be quickly cooled at the completion of the reaction.

Next, can you suggest the applications of microwave i.e., the uses of microwave at home and/or industrial level. We have highlighted few of the applications here for your knowledge.

12.3.3 Microwave food processing applications

Table 12.2 lists microwave applications in food processing. In some instances, these processes can be extended to other similar products, e.g. the pasta drying process could be used in some variation in the process to dry many other food and agriculture products. Microwave vacuum drying has been applied to grains, seeds and fruit juices and could also be applied to various vegetables and other heat sensitive materials. Microwave sterilization of foods in hermetically sealed containers is just now coming of age and has a great future.

Table 12.2 Food applications of microwave

PROCESS	PRODUCTS
Tempering	meat, fish, poultry
Cooking	bacon, meat patties, Sausage, potatoes, Sardines, chicken.
Drying	pasta, onions, rice cakes, egg yolk, snack foods, seaweed
Vacuum drying	orange juice, grains, seeds.
Freeze drying	meat, vegetables, fruits
Pasteurization	bread, yogurt.
Sterilization	pouch packed foods
Baking	bread, donuts
Roasting	nuts, grains
Blanching	Vegetables, potatoes, corn, fruits
Rendering	lard, tallow

Microwaves are commonly used for reheating of pre-prepared chilled and frozen foods. The defrosting of frozen foods is best accomplished in stages with resting periods allowed for heat conduction within the food, so eliminating the formation of hot spots due to uneven microwave absorption. Most commercial microwave ovens have facilities that allow programming of a suitable sequence for the defrosting of frozen foods.

Whether used in combination with conventional heating or alone, microwaves have a place in industrial processing. Five potential applications are:

1. Baking: Microwave's ability to speed up the internal heating can accelerate the baking process. Microwave heating can be combined with convection heating to create a crispy crust and pleasing appearance in less time.
2. *Curing:* Because it leads to rapid heating throughout the product, microwaves may be used for bulk polymerization reactions that are heat initiated.
3. *Blanching:* When combined with a humid or steam atmosphere, rapid uniform heating with microwaves can be effective for blanching fruits and vegetables. Microwave processing does not incur the leaching losses associated with hot water or steam blanching.
4. *Removing Solvent:* Many solvents are efficiently vaporized with microwaves, permitting solvent removal at relatively low temperatures. Microwaves also can be used to cure glue and other adhesives.
5. *Moisture Leveling:* Because their heating effect is roughly proportional to the moisture content, microwaves can be used to equalize the moisture content within a product that has a non uniform moisture level.

Finally, having read about the advantages and applications of microwave processing, can you now critically analyze and suggest the advantages of microwave over conventional heating. To help you in this task we have highlighted the points in the next section, where we have compared microwave and conventional heating.

12.3.4 Microwave v/s conventional heating

The primary difference between the supply of heat by microwaves or by the conventional thermal ways is in the initial distribution of heat. In conventional heating, the heat energy is applied to the outside surface of the food and it is conducted from there to the center of the food. With microwaves, food is heated principally by the generation and deposition of heat throughout a 3 dimensional space in the food itself. This is, therefore referred to as volume heating, because its effect is throughout the product. The food container and air in the oven will be heated only after they receive heat from the food. Thus, very rapid heating times can be obtained with direct coupling of the energy in to the product rather than placing the reliance on the transfer of heat energy through the container surface and subsequent conduction to the center of the mass.

The main advantage of microwave oven over conventional electric and gas ovens is its high thermal efficiency in converting the electrical energy to heat in the food. In ordinary ovens, a major portion of the energy is lost in heating the air that surrounds the food; fairly a good amount escapes through the vent, besides being lost through the conduction to the outside air. In contrast, almost all the heat generated by microwaves, which reaches the interior of the oven, is produced inside the food material itself. According to the reports, microwave ovens are 40% efficient as compared to 14% for standard electric ovens and 7% for gas ovens.

In this section, we shall begin our discussion on another major method of food processing, involving the use of radiation i.e., food irradiation.

12.4 FOOD IRRADIATION

Food irradiation is one of the food processing technologies available to the food industry to control organisms that cause food-borne diseases and to reduce food losses due to spoilage and deterioration. Irradiation is *the use of radiation from gamma rays, x-rays, electron beams or radioactive materials on food.* The radiation sterilizes food and kills bacteria and controls certain factors that cause food spoilage, but does not make the food itself radioactive.

Food irradiation technology, too, offers some advantages over conventional processes. Each application should be evaluated on its own merit as to whether irradiation provides a technical and economical solution that is better than traditional processing methods.

For products where irradiation is permitted, commercial applications depend on a number of factors including the demand for the benefits provided, competitiveness with alternative processes and the willingness of consumers to buy irradiated food products. There are a number of applications of food irradiation. For each application, it is important to determine the optimum dosage range required to achieve the desired effect. Too high a dosage can produce undesirable changes in texture, colour and taste of foods. Irradiation can extend the shelf-life of foods in a number of ways. By reducing the number of spoilage organisms (bacteria, mould and fungi), irradiation can lengthen the shelf life of fruits and vegetables. Since ionising radiation interferes

with cell division, it can be used as an alternative to chemicals to inhibit sprouting and thereby extend the shelf life of potatoes, onions and garlic. Exposure of fruits and vegetables to ionising radiation slows their rate of ripening. Strawberries, for example, have been found to be suitable for irradiation; their shelf life can be extended three-fold, from 5 to 15 days.
Ionizing radiations can also be used as an alternative to chemical fumigants for disinfestation of grains, spices, fruits and vegetables. Many countries prohibit the import of products suspected of being contaminated with live insects to protect the importing country's agricultural base. With the banning of certain chemical fumigants, irradiation has the potential to facilitate the international shipment of food products.

Recently, there has been a lot of interest and controversy linked with irradiated foods. In this context, it is important to know about the global development and international trade perspective on this issue. The next sub-section throws some light on this interesting issue.

Global Developments and International Trade

Are irradiated foods wholesome and safe? What is the consensus on wholesomeness? Let's find out. In 1980, an FAD/IAEA/WHO Expert Committee reviewed in detail all the accumulated data on food irradiation from the past 40 years. The Expert Committee concluded that irradiation to an overall dose of 10 kGy (kilograys) presents no toxicological hazard and introduces no special nutritional or microbiological problems, thus establishing the wholesomeness of irradiated foods up to an overall average absorbed dose of 10 kGy.

Data were insufficient to formulate conclusions on applications of food irradiation above 10 kGy. Data on radiation chemistry, nutritional and microbiological aspects of food treated above 10 kGy is currently being compiled.

In 1983, the Codex Alimentarius Commission, an international group that develops global food standards for the FAO and the WHO, incorporated the 1980 Expert Committee's conclusions regarding the wholesomeness of irradiated foods into the Codex General Standard for Irradiated Foods. This proposed international standard was submitted to member countries to accept or to modify according to individual country needs. Currently, most countries that allow food irradiation approve its use on a case-by-case basis.

The Codex Alimentarius Commission has also adopted a Recommended International Code of Practice for the Operation of Radiation Facilities for the Treatment of Foods. It is intended to serve as a guide for irradiator operators and government regulators.

What about the international trade?

More than 30 countries have given clearances for the use of food irradiation to process some 40 food items and approximately 30 facilities world-wide treat food by irradiation processing. Approvals for additional items are being considered in many countries and many food irradiation facilities are being planned. It was anticipated in 1988 that by 1990 there could be approximately 50 commercial/demonstration irradiators in 25 countries.

Check Your Progress Exercise 2

1. Fill in the blanks:

(i) Microwaves are ------------------------------with a frequency between ------------------------

(ii) Microwaves heat a product from --

(iii) Heating products which -------------------------moisture content is difficult as compared to --moisture content.

(iv) One of the purpose of food irradiation is to --- .

(v) A high radiation dose can lead to ------------------, -------------------- and ----------------- .

(vi) Ionising radiations can extend the shelf life and inhibit sprouting because they ------------- --

2. Describe the mechanism of microwave processing.

----

3. What are the factors that influence microwave heating pattern?

----

4. List a few advantages of microwave heating over conventional heating.

----

5. Mention a few potential applications of microwave heating.

----

6. Define irradiation.

Now let us study about one of the ancient methods of food processing and preservation i.e., Fermentation.

12.5 FERMENTATION

Fermented foods, whether from plant or animal origin, are an intricate part of the diet of people in all parts of the world. It is the diversity of raw materials used as substrates, methods of preparation and sensory qualities of finished products that are so astounding, as one begins to learn more about the eating habits of various cultures. The preparation of many indigenous or "traditional" fermented foods and beverages remains as a household art. The preparation of others, e.g., soy sauce, has evolved to a biotechnological state and is carried out on a large commercial scale.

Fermented foods which are reviewed in the following section, including bread, fermented dairy products, vegetables and sauces, coffee and cocoa, have been scientifically studied during many decades and knowledge about these foods keeps pace with developments in modern science. This resulted in production methods that follow advances in modern technology. Fermented foods, which are popular in Japan include shoyu (fermented soybean products), miso (fermented soybean products), natto (soybean products, made by fermentation with bacteria) and sake, have followed the same modern trend. In contrast, some other fermented foods of Asian and African countries including *emple, gari, kimchi* and some other have come to the attention of modern scientists only in the last two decades and many others have not yet been studied at all. Consequently, most of these foods are still manufactured according to traditional less technologically advanced methods, using simple equipments and produced on a small village industrial scale or just at home for family consumption.

Before we continue further with our study on fermented foods, let us first understand what we mean by fermented foods. Basically, fermented foods are *agricultural products which have been converted by enzymic activities of microorganisms into desirable food products whose properties are considered more attractive than those of the original raw materials.* In addition to its external attractive properties, its nutritional values and keeping qualities are in many cases better than the raw materials. Moreover, if the manufacturing procedures are followed, the foods are usually safe for consumption. All of these beneficial properties of the final product increase the economic value of the original agricultural commodity. Generally, traditional methods of manufacturing fermented foods are not complicated and expensive equipment is not required. Therefore, fermentation of indigenous foods is considered as an inexpensive and effective means of food production that could be utilized in alleviating World food problems. Some common fermented foods used in Indian cuisine are highlighted herewith, for your reference and better understanding of the fermentation process.

Box 1: Fermented Foods of India

You may be familiar with the fermented foods used in India. A brief description of these foods follows as:

Idli: Idli is a fermented and steamed snack made from various proportions of rice and Black gram. It is typically eaten for breakfast and is especially popular in South India, although consumed throughout the country. Proportions of rice to Black gram cotyledons, used to prepare *idli* range from 1:4 to 4:1, depending upon the taste preference and availability of ingredients. *Idli* containing higher amounts of rice is characterized by a more predominant starchy flavour. Other ingredients such as cashew nuts, ghee, chilli peppers, ginger, fried cumin seeds or curry leaves may be added to the dough in small quantities to impart an additional flavour.

Dehulled Black gram and rice are washed and soaked in water separately for 5 to 10 hours at an ambient temperature. The amount of soaking water can vary from 1.5 to 2.2 times the dry weight of the black gram or rice. About 1.5 times water over dry ingredients was optimum for fermentation and for *idli* preparation. After soaking, the Black gram is ground with water to give a coarse paste, whereas the rice is ground to give a smooth gelatinous paste. Salt (about 0.8%) is added to the combined mixture of pastes and fermentation is allowed to proceed for 15 to 24 hours. Upon steaming, the softy, spongy final product resembling a sour bread or pancake is consumed, while still hot. The spongy open texture of *idli* is attributed to the protein (globulin) and polysaccharide (arabino-galactan) in Black gram.

Acidification and leavening are the most important processes which occur during fermentation. *Idli* batter volume increases 1.6 to 3.1 times, and the pH falls from an initial 6.0 to 4.3 during fermentation. Thus, the sour taste of *idli* is a necessary and desirable characteristic. While several reports have been made on the microbiology of *idli* fermentation, no comprehensive studies on the microorganisms involved and the changes brought about by them have been made. Bacteria identified as a part of the microflora responsible for the production of good *idli* include *Leuconostoc mesenteroides, Lactobacillus delbrueckii, L.fermenti, L.lactis, Streptococcus faecalis* and *Pediococcus cerevisiae.* Yeasts involved in *idli* fermentation include *Oidium lactis (Geotrichum candidum), Torulopsis holmii, T.candida* and *Trichosporon pullulans.* Soured buttermilk or yeast is sometimes added to the dough to reduce the fermentation time and, consequently, influence the microbial profile of the total fermentation process.

The lactic acid bacteria are obviously responsible for pH reduction in *idli*. They may also contribute significantly to the improvement of the nutritional value of unfermented Black gram and rice. The effects of *Leuconostoc mesenteroides, Lactobacillus fermenti, L.delbrueckii* and *Bacillus* species on changes in amino nitrogen, free sugar, thiamin, riboflavin and inorganic phosphate content as well as sensory qualities of traditional *idli*, rice-soyabean *idli* (black gram replaced by soyabeans), *dhokla* and *khaman* have been investigated. The increase in thiamine and riboflavin contents as a result of fermentation is particularly notable in the light of inadequacies of these vitamins in the diets of some Indian children. Bacteria may also play a role in the breakdown of phytate present in Black gram. A strain of *L.mesenteroides* isolated from soyabean *idli* secretes *–N-acetylglucosaminidase* and *–D-mannosidase,* which are involved in the hydrolysis of hemagglutinin, has been reported.

There is some debate as to the effect of fermentation of *idli* on the Protein Efficiency Ratio (PER). The PER of *idli* was improved as a result of fermentation. In some cases, an increase in methionine content resulting from fermentation has been observed. A loss of 77% of the inorganic sulfur during black gram and rice blend fermentation was also reported. Using in-vitro digestion techniques, an improvement in the availability of essential amino acids during the fermentation has been reported. Studies on the substitution of other *Phaseolus* species for Black gram have shown that the products with acceptability comparable to that of a traditional *idli* can be prepared. Evaluation of soyabean *idli* prepared using several types of bacterial inoculants has also been attempted. It was concluded that chemical, physical and organoleptic characteristics of the soybean products are not unlike that of traditional *idli. Idli* containing Great Northern beans (*Phaseolus vulgaris L.*) in place of Black gram, has also been evaluated. *Idli* containing Great Northern beans had somewhat different flavour and a sticky top surface. The incorporation of Great Northern beans into *idli* would offer the advantage of increased roughage.

Waries: Waries (*Punjabi waries*) are the spicy condiments shaped in the form of a ball about 3 to 8 cm in diameter, which are used in cooking with vegetables, grain legumes or rice in India. Dehulled grain legumes are soaked in water, ground into a coarse paste and mixed with spices and a small amount of paste from a previous fermented batch. Some spices used include asafetida, caraway, cardamom, cloves, fenugreek, ginger, red pepper and salt. After fermenting as a mass for 4 to 10 days at ambient temperature, the paste is formed into balls and air-dried in the sun. The surface of the balls becomes sealed with a mucilaginous coating during the drying process, thus entrapping gases produced by the yeasts present inside. Yeasts identified as contributing to fermentation of *waries* are *Candida spp. and Saccharomyces cerevisiae.* Waries can also be prepared from Bengal gram and mung bean flours.

Papadam: Papadam is similar to *waries*, but does not contain fenugreek or ginger. These circular tortilla-like wafers are prepared from a mixture of Black gram paste and spices, which have been fermented for 4 to 6 hours. Yeasts responsible for fermentation are the same as those found in *waries*. *Papadams* are served either roasted or deep fat fried and consumed as a relish.

Dhokla: Dhokla is a steamed fermented food prepared from a mixture of wheat semolina and Bengal gram flours (2:1 ratio). The flours plus about 3% salt are made into a thick batter by adding water and then allowing them to ferment by adding water and then further allowing them to ferment for about 14 hours. Chopped fenugreek leaves are added to the dough before steaming for 20 minutes in a pan with oil. The product is then cut into pieces and may be seasoned with cracked mustard seeds before eating as a condiment with other breakfast foods in India.

Khaman: Khaman is a steamed and fermented condiment prepared from Bengal gram flour in India. Dehulled seeds are washed, soaked for 4 hrs., ground with water (2:3, Bengal gram:water) and seasoned with salt before fermenting for 12 hrs. Like *dhokla*, the dough is then steamed and seasoned with mustard seeds before eating. Thiamine and riboflavin are reported to increase significantly.

Kenima: Kenima is a fermented soyabean product prepared in Nepal, Sikkim and Darjeeling districts of India. Soyabeans are soaked over night, dehulled and cooked in water for 2 to 3 h. The cooled soybeans are inoculated by the addition of a portion from a fermented batch, wrapped in leaves and fermented at 22^o C to 23^oC for 24 to 48 hrs. The microorganisms responsible for the mucilaginous end product known as kenima have not been identified. When deep fat fried and salted, *kenima* has a nut-like flavour, much like that of tempeh.

Jalebies: Jalebies are a spiral shaped, deep fat fried confectionary product made from fermented wheat flour. Chickpea flour may be added to the fermented wheat flour before the paste is fried. The fresh fried *jalebies* are dipped in the sugar syrup.

Kurdi: Kurdi is a deep – fat fried, salty, crispy product prepared from fermented wheat. Wheat grains are soaked for about 5 days at 30°C, before the slurry is fried to make the snack, which is consumed in Central India. Little is known about the fermentation process, although yeasts and lactic acid bacteria are undoubtedly involved.

Kanji: Kanji is a fermented beer-like beverage, common in the households and market places in India. North Indian *kanji* is prepared from purple or occasionally orange cultivars of carrots, beets, spices, a portion from a previous batch of *kanji* and water. South Indian *kanji* is prepared in two steps, the first involving the preparation of *torani* (a fermented rice liquor) and the second involving the fermentation of *torani* and a mixture of vegetables, spices and water. *Hansenula anomala var. anomalahas* been isolated from *kanji* collected in North India (Delhi) whereas *H. anomala, Candida guilliermondii, C. tropicalis and Geotrichun candidum* have been isolated from the South Indian *kanji.*

In the recent years, a growing number of food scientists and microbiologists have recognized the value of indigenous fermented foods as a potential source of food supply for many parts of the world. Special attention is paid to the microorganisms and their role in the fermentation process. Consequently, in this unit you will find that we have classified indigenous fermented foods according to the microorganisms involved in the process. Let us learn about these different fermented foods used worldwide.

12.5.1 Types of fermentation and fermented foods

Some foods are mainly fermented by moulds, others mainly by bacteria, another category by a mixture of moulds and yeasts and a number are firstly fermented by moulds followed by fermentation with a mixture of bacteria and yeasts. We will learn about these different fermented foods, starting with the foods prepared by mould fermentation.

12.5.1.1 Foods Fermented by Moulds

The most well known foods which are manufactured mainly by the activity of moulds are *Temphe* (fermented soyabean product from Indonesia), *Oncom and Angkak*. Tempeh is made by fermentation of soybeans with *Rhizopus Oligosporous*, *Oncom* is made form peanut press cake and is fermented by *Neurospora* species, *Angkak* is made by the fermentation of rice with *Monascus purpureus* to produce red coloured kernels. The product itself is not a food, but it is used to give an attractive red colour to certain products made of fish and soybeans to certain alcoholic beverages. What is the role of moulds in fermentation of foods? Read and find out.

Role of the Moulds: The different functions of moulds in food fermentation include:

- *Synthesis of Enzymes*: One of the most important functions of the mould in food fermentations is synthesis of enzymes. These enzymes generally decompose complex compounds including proteins, carbohydrates and fats into smaller molecules. At the same time, other compounds may be synthesized from the food substrate. These complex chemical changes are accompanied by changes in the original properties of the raw materials. Taste, flavour, texture, colour, palatibility and other properties of the raw materials are usually modified in such a way that the final product becomes more attractive to the consumer.

- *Mould Growth*: Mould growth on certain products contributes to the appearance of the food, which is desired by the consumer. For example, *Neurospora* spp. provides *oncom* - cakes with a coating of its pink-orange coloured and powdery conidia. *Rhizopus oligosporus* covers *tempeh* with a clean white mycelium surface layer and additionally has the function of binding together the soybeans into a solid, compact cake.
- *Synthesis of Colouring Compounds*: The function of *Monascus purpureus* during fermentation of *angkak* is to produce the red-coloured compound monascorubrin ($C_{22}H_{24}O_5$) and the yellow pigment monascoflavin ($C_{17}H_{22}O_4$) in soaked rice.
- *Protection of the Product*: In spite of the deep-seated prejudice against mouldy products in the Occidental culture, which seems to be justified by the discovery of aflatoxin and other mycotoxins in the last two decades, studies on certain mould species, which are traditionally used for fermentation of Oriental foods, showed that they do not produce toxins, but, on the other hand, they resist accumulation of certain toxins which otherwise will be produced by other microorganisms in the food. This could be considered as a protection of the product against other harmful microorganisms. A good example of such a protective role is demonstrated by *Rhizopus oligosporus*, the mould species that is used for fermentation of *tempeh*. This mould species does not produce aflatoxin. On the contrary, if aflatoxin is already present in the growth substrate, its content could be lowered by *R.oligosporus* to about 40% of its original content. In addition, it was found that *R. oligosporus* inhibits growth, sporulation and aflatoxin production by *Aspergillus flavus*. Extended studies showed that other species of *Rhizopus*, including *R. arrhizus*, *R. oryzae* and *R. chinensis*, do not produce aflatoxin and on addition, inhibit aflatoxin production by *A. flavus* and *A. parasiticus* if they grow in the same substrate. Another study showed that when, during fermentation of coconut press cake into tempeh bongkrek, contamination takes place with *Pseudomonas cocovenenans*, toxin production by these bacteria under certain conditions is inhibited by *R. oligosporous*.

12.5.1.2 Foods Fermented by Bacteria

In vegetable, fish as well as some soybean fermentations, one or more species of lactic acid bacteria play an important role. Their production of organic acids not only contributes to the desired taste and flavour of the final product, but it also makes the substrates unfavourable for proliferation of spoilage and other undesirable microorganisms. At the same time, the acids make the substrate more suitable for growth of desirable microorganisms, which improve the properties of the food. The role of carbon dioxide produced by *Leuconostoc mesenteroides* is in different products not the same. In vegetable fermentations, it provides an anaerobic condition, which inhibits proliferation of aerobic microorganisms. In fermentation of *idli* and *puto*, carbon dioxide is essential for leavening the dough. As you read through this section you will realize that foods fermented by bacteria are made of different raw materials. In each of these raw materials, the bacteria involved have a different role. Let us then find out.

A. Fermented Vegetable Products: Production of fermented vegetables on a large scale took place for the first time during construction of the Chinese Great Wall in the third century B.C. The foods which were made of cabbage, radish, turnip, cucumber and other vegetables, were supplied as a portion of the workers' rations. In general, bacterial activity during fermentation of vegetables follows the same pattern. The majority of microorganisms on vegetables consists of strains of soil and water species of genera such as *Pseudomonas, flavobacterium, Achromobacter, Aerobacter, Escherichia and Bacillus.* Lactic acid bacteria, which are required for the desired fermentation, are originally present in comparatively low numbers. At the start of the fermentation, salt is added in such a concentration (2.5-6.0%) that undesirable putrefactive bacteria are kept under control, long enough to favour lactic acid producing bacteria to proliferate. Under these conditions, *Leuconostoc mesenteroides* is considered to establish proper environmental conditions for proliferation of other species of lactic-acid bacteria rather than producing favourful compounds. *Lactobacillus brevis* is important in imparting character to the final product and is often characterised by its ability to ferment pentose sugars. *Lactobacillus plantarum* is the high acid-producing species, and together with *P. cerevisiae* plays a major role, particularly in fermentation of vegetables in brine. In brine, acidity beyond 1% is rarely attained, while in a dry-salted vegetable an acidity of 2.0-2.5% can be reached if sufficient sugar is present.

B. Fermented Fish Products: Large quantities of small fish are fermented to produce fish or shrimp sauces and pastes in South East Asia. The basic procedure is to mix the freshly netted small and trash fish with sea salt to such an amount that the extracted fish juices contain about 20% salt in final product. The fish sauces are salty condiments to be added in small quantities to other foods. Similar process in which less hydrolysis occurs, lead to fish or shrimp pastes. The pastes may be mixed with cereals. Despite their high protein content, these products are of limited nutritional value because of the low level of consumption. The role of microorganisms in the fermentation process is clearly different form that in fermented vegetable products. The high salt content of these products leaves only salt-tolerant microorganisms survive. These originated from the natural microbial population of the fish or shrimp itself, and from the salt and microorganisms introduced during the manufacturing process from fermentation tanks, equipments and workers.

C. Fermented Seeds: Here we shall discuss on a few fermented seeds which are generally area-specific. Let us start our discussion on fermented soyabean products.

Natto: One of the few soybean products, which are made by fermentation with bacteria, is the Japanese *natto*. It is made of soaked and cooked soybeans which traditionally are wrapped in rice straw and left for one or two days in a warm place. The rice straw is considered to have various functions. It supplies the essential microorganisms for the fermentation, provides the aroma of straw to the product, which is considered pleasing, and absorbs partly the unpleasant odour of ammonia, which is released during the fermentation. The essential microorganisms for this fermentation were found to be *Bacillus natto,* which is classified as a related strain of *B. subtilis*. During the fermentation, the beans become covered with a viscous, sticky polymer. The product is considered of good quality if long stringy threads are formed when two beans are pulled apart. *Natto* has a slimy appearance and has a gray colour; its flavour is strong and persistent. It is consumed with rice or used as a side dish. Although *natto* is well known in Japan because of its exceptional properties, it is not as popular as other fermented soybean products, including *miso* and *shoyu*. Similar to other traditional Japanese fermented foods, *natto* has been scientifically studied, and production on a modern technological base using a pure culture starter has been developed. One of the new developments is production of powdered *natto*, which could be added to biscuits or soup.

Thua-nao: Thua-nao is a food product of Thailand, which closely resembles *natto.* Unlike *natto*, however, *thua-nao* is lightly mashed into a paste to which salt and other flavouring agents are added.

Dage: Dage is an Indonesian food product made of different oil-rich seeds *(Mucuna pruriens, Aleurites moluccana, Arachis hypogae* and others) or their residues. Like traditional *natto*, it is subjected to natural fermentation by bacteria. On a very limited scale, *dage* is made at home and used as a side dish or as an ingredient in preparing certain dishes. Not much is known about the microbiology and biochemistry of this type of products, which is of very limited importance.

D. Fermented Starch – Rich Raw materials: Fermentation of starch–rich substrates by bacteria into fermented foods is practised mainly in Africa. The most important raw materials are maize *(Zea mays)* and cassava (*Manihot sp.)*

E. Fermented Maize Products: Not less than 20 different fermented maize products are known in African countries. Manufacture of these foods follows basically the same outline. Corn is soaked for one to three days, ground and mixed with some water to make thick dough. During preparation of *banku, kenkey, akpler* and other foods, the mash is left one to three days for fermentation. However, if *ogi or agidi* are to be made, the mash of ground maize is diluted with water, sieved to remove the bran and the filtrate left for fermentation. Presumably, the fermentation process in the thick maize dough as well as in the diluted maize suspension follows the same pattern. The microorganisms involved may be the same as in *ogi*. It was found that *Corynebacterium spp*. hydrolyzed starch and initiated acidification; later on, it was replaced by *Aerobacter cloace*. The highest acidity, mainly attributable to lactic acid was produced by *Lactobacillus plantarum*. At the beginning of the souring period, *Saccharomyces cerevisiae* proliferates rapidly while, at the end, *Candida mycoderma* was predominant. These two microorganisms were considered to contribute to the flavour of the product and to its enrichment with vitamins. *Aerobacter cloacae*, on the other hand, decreased the thiamin and panthothenic acid contents, but increased the riboflavin and niacin contents. In most cases, the fermented mash is concentrated by cooking until it becomes a thick porridge or cake.

F. Fermented Rice Products: We are all familiar with *idli, dosa* etc., the fermented rice products from south of India. *Idli* is soft and spongy steamed bread, which is now popular all over India. It is made from a mixture of milled rice and dehulled Black gram (*Phaseolus mungo*), which is left for natural fermentation overnight. Instead of yeasts, which are usually required for manufacturing bread, the predominant microorganism producing acid and gas in the natural fermentation of *idli* is *Leuconostoc mesenteroides.* This bacterium is generally present on Indian

Black gram. In the later stages of the fermentation, *Streptococcus faecalis and P. cerevisiae* may also play a role. It was reported that the fermentation does not improve the nutritional value, but it does improves the palatability of the product in terms of flavour, taste and texture. When the dough has been raised sufficiently, it is steamed and is served while it is hot. It is a common snack or breakfast food used almost daily in the homes and restaurants in India. Similar foods in India are *dosa and appam* which are made by fermentation of a mixture of rice, other legumes and certain ingredients. These are essentially pancakes, which are prepared on a hot pan after the fermentation is finished. *Puto* from the Philippines is essentially steamed bread or cake made by natural fermentation of fine-ground flour of glutinous rice. The carbon dioxide for leavening the dough is presumably produced by the same species of lactic acid bacteria as for manufacture of *idli*.

G. Fermented Cassava: In several countries of West Africa (Nigeria, Ghana), *gari* is an important staple food. For its manufacture, fresh cassava *(Manihot utilissima)* is peeled, grated and the greater part of the juice squeezed out. The remaining pulp is left for three or four days for natural fermentation to occur. In the first stage, *Corynebacterium spp.* attacks the starch with production of organic acids. The lower pH value causes hydrolysis of a cyanogenic glucoside with liberation of gaseous hydrocyanic acid. Organic acids also make conditions favourable for growth of *Geotrichum candidum*. This microorganism produces a variety of aldehydes and esters, which are responsible for the characteristic taste and aroma of *gari*. Other reports also mentioned the probable role of *Leuconostoc spp*. and *Streptococcus faecium*. The fermented pulp is finally fried in iron or earthenware pans. Sometimes the pan is greased with palm-oil, in which case the *gari* comes out yellow. The resulting product is dry and granular and has the property of swelling up in cold water. It can be consumed simply with water, without any cooking. Sugar may be added, or it may be mixed with spices (pepper) or other foods like fish or egg.

H. Fermented Plant Juice: Throughout the tropics, the sugar of palm trees of many species is spontaneously fermented into alcoholic beverages. The microflora isolated during this fermentation are rather complex, but it is considered certain that *Zymomonas spp*. are largely responsible for the alcoholic content (4 - 5%) and carbon dioxide formation. The fruity odour and the taste of palm wine may be also due to production of some acetaldehydes by *Zymomonas* *spp.* Lactic acid bacteria contribute to the acidity by producing small amounts of lactic and acetic acids. Similar bacterial alcoholic fermentation occurs during fermentation of the juice of certain species of *Agave* in Mexico to produce the alcoholic beverage pulque. Only small numbers of yeast cells are usually found in these alcoholic beverages. Because formation of alcohol and carbon dioxide from sugar fermentation is a characteristic of yeasts, alcoholic fermentation by bacteria is not a common process.

12.5.1.3 Foods Fermented by a mixture of moulds and Yeasts

After focusing on bacteria, here, we shall look at the fermented foods produced by the action of moulds and yeasts.

Ragi: Ragi itself is not a food; it is an inoculum used to induce fermentation of certain food products. It is known in many Asian countries under different names. Most probably, its origin is China, where 'chu' was already described in the Old Chinese classics as the most important ingredient in the manufacture of alcoholic beverages. Later records gave thorough descriptions of its preparation and applications. It is made of rice flour, which is moulded into flattened round cakes of 2-3 cm diameter.

Numerous fungi and yeasts have been isolated from *ragi*. Of the many mould species which have been isolated from *ragi*, *Mucor* and *Rhizopus* species are the most important. *Chlamydomucor oryzae*, recently re-identified as *Amylomycesrouxii,* plays a major role. Yeast srains isolated from *ragi* included species of *Candida, Endomycopsis* and also *Saccharomyces.* They produce alcohol from the sugar, which is produced from starch by the mould. It was found that, for a good fermentation of glutinous rice into good quality tape, a combination of *Chlamydomucor oryzae* and *Endomycopsis chotadi* was essential. This combination of microorganisms was the starting point for later studies on tape fermentation.

When *ragi* is innoculated into a starch-containing substrate like steamed rice, cassava, maize or sorghum, a soft juicy product with a sweet, mild sour taste and mild alcoholic flavour is obtained after two or three days incubation at 25-30^{o}C.

Such a product made of rice is known in different countries under different names. It is consumed as such, without any preparation and is considered as a delicacy. In China, *lao-chao* has a unique place in the diets of new mothers. It is believed that *lao-chao* helps them regain their strength.

In Indonesia, a confectionary is made by separating the juice which is produced during the fermentation of tape ketan. Traditionally, the liquid is dried in the sun until a solid cake is obtained. It is considered a delicacy, particularly for children and is known under the name of *brem.*

When fermentation of rice is extended to several weeks, more alcohol and more liquid are produced. To produce *rice wine,* the liquid is expressed and kept for clarification and ripening during several months. The beverage is well known under different names in different countries. Depending on the fermentation time, the alcohol content differs and a concentration of 15% can be reached. By distillation, a beverage can be obtained with approximately 50% alcohol.

In Indonesia, peeled, washed and steamed cassava tubers are fermented by inoculation with ragi to produce *tape-ketella* or *peuyeum.* The final product is food with a soft texture, a lightly sour-sweet taste and a mild alcoholic flavour. It is considered as a delicacy and is usually consumed without additional preparation. Sometimes it is shortly deep-fried in coconut oil before consumption. It may also be mixed with other ingredients to make a kind of pie.

12.5.1.4 Foods firstly fermented by moulds followed by fermentation with a mixture of bacteria and yeasts

The most studied foods in this category are those developed in Japan from traditional foods produced on a scale ranging from a house industry to high-industrialized products. These include *shoyu,* the Japanese type of soy sauce, and *miso*, a pasty product made of a mixture of rice and soybeans. For its fermentation, the traditional inoculum T*ane koji* is applied. Let's get to know about these products.

a) Tane koji: Presumably, this starter originated from ancient China and was introduced into Japan in about 200 A.D. Once in Japan, it followed a typical Japanese way of development.

From a traditional inoculum, it has developed into an inoculum made of pure cultures of mould strains whose properties are studied and controlled with the newest methods of modern microbiology. It is a green-yellow powder consisting of mould spores of one or more selected strains of *Aspergillus oryzae and A. soyae* which produce protease, amylases and a great variety of other enzymes. Modern day *tane koji* for a particular fermentation is composed of spores of several strains of *A.oryzae* mixed together in a definite proportion in order that various enzymes can be produced in the proper amounts during the different stages of fermentation.

b) Soy Sauce: Soy sauce is a brown coloured, liquid condiment which has different names in different countries. It is made by a two-stage batch fermentation, which involves the biochemical activities of moulds, bacteria and yeasts. The first stage consists of growing one or more mould species on cooked soybeans or on a mixture of soybeans and wheat, oats, rye or tapioca. Japanese shoyu is made from equal amounts of soybeans and wheat. For the fermentation of Japanese shoyu, the raw materials are inoculated with Tane koji, which contains spores of selected strains of *Aspergillus oryzae. and A. soyae*. In less sophisticated traditional soysauce factories throughout South East Asia, mould species grow spontaneously on the soybeans by natural contamination from the air and from the bamboo trays on which soybeans of former batches were incubated. The moulds involved are species of *Aspergillus, Rhizopus* or *Mucor.* Some Indonesian kecap manufacturers inoculate the cooked soybeans with tempeh inoculum, which contains spores of *Rhizopus oligosporus*. In this first stage of mould fermentation, enzymic breakdown of insoluble protein in the raw materials into soluble polypeptides, peptides and amino acids takes place by extracellular proteases of the mould. Starches are hydrolyzed to disaccharides and monosaccharides by amylase secreted by the mould, while extracellular invertase hydrolyses sucrose in the soybeans.

When after two or three days, mould growth has reached a certain level, the moulded raw materials is placed into brine containing 15-20% sodium chloride, in which the second stage of fermentation takes place. The contribution of bacteria and yeasts in this second part of the fermentation to the development of flavour and taste of soysauce is well documented. After a fermentation of at least six months duration and traditionally two or three years, the liquid is removed by decanting or siphoning. In modern factories, the liquid is expressed with a hydraulic press from the residue. After final treatments including pasteurization, clarification, filtration and eventually addition of chemical preservatives, the brown liquid is bottled for distribution to the consumers. Basically, there are two major kinds of soy sauce. The Chinese type is made of soybeans alone or from a mixture of soybeans and wheat with a higher percentage of the soybeans. In some cases, wheat could be substituted by wheat bran, oats, kaoliang and rye. An Indonesian kecap manufacturer uses tapioca-flour for this purpose. The Chinese type soy sauce is of high specific gravity and viscosity and high nitrogen content; it is dark in colour and is sometimes sweetened with cane sugar. The Japanese type soy sauce is made of equal amounts of soybeans and wheat. It is lower in viscosity and lighter in colour than the Chinese type.

c) Other Fermented Soybean Products: Several other soybean products as indicated in Table 12.3 are basically similar to soy sauce with respect to micro-organisms and fermentation principles, although the composition of raw materials, methods of manufacture, consistency and appearance of the final foods are all different. In the first stage of fermentation, moulds are grown on cooked soybeans or on a mixture of soybeans and cassava flour for the manufacture of *taoco.* In many Japanese families, breakfast consists of cooked rice and *miso* soup. *Miso* is also used as seasoning agent to prepare fish and vegetable dishes. For production of *miso*, the moulds are grown on steamed rice. The moulds are introduced as spores of *Aspergillus oryzae* and *A. soyae* in *tane koji*. A mixture of soybeans and wheat flour is used for the manufacture of *hamanatto*. The other less sophisticated products could be purposely inoculated or naturally contaminated with strains of *Aspergillus oryzae, Rhizopus oryzae, R. oligosporus* or a mixture of two or more species.

Table 12.3 Soybean foods produced by a two stage fermentation

Country	Product
Japan	Hamanatto
Japan	Miso
Orient	Soy sauce
Indonesia	Taoco
Philippines	Tao-si
China Japan	Tou-shih

We conclude our discussion on fermented foods, by presenting a brief summary of specific aspects of the fermented foods discussed so far.

Check your Progress Exercise 3

1. What do you mean by the term 'fermented foods'?

   ----

2. List a few fermented foods that are consumed in India.

   ----

3. What are the functions of moulds in the fermentation of foods?

   ----

4. Fill in the blanks:

(a) Some of the beneficial properties of fermented products over original agricultural commodity are --------------------, -------------------, ----------------------, ------------------ and ------------------- .

(b) The red-coloured compound is synthesized by ---during fermentation of angirak, while yellow pigment in soaked rice.

(c) In fermentation, salt is added in a concentration of ----------------------- .

(d) -------------------------------- alongwith *P.cerevisiae* plays a major role in the fermentation of vegetables in the brine.

(e) The two micro-organisms which contribute to the flavor in fermented maize products are------------------------- and ------------------------ .

12.6 DEEP FAT FRYING

All of us enjoy fried products, whether home-made or bought from market. Let us see what is the technology involved in frying process and the factors affecting it.

Deep fat frying is considered one of the oldest processes of food preparation. *Deep fat frying can be defined as a process of cooking and drying through contact with hot oil and it involves simultaneous heat and mass transfer.* For decades, consumers have desired deep-fat fried products because of their unique flavor-texture combination. During deep fat frying, a food product's surface is sealed when the product is immersed in hot oil so that all the flavors and the juices are retained in a crispy crust. Many foods have been successfully deep fat fried, examples include potato chips, french fries, doughnuts, extruded snacks, fish sticks and the traditional fried chicken products.

The frying technology is important to many sectors of the food industry, including suppliers of oils and ingredients, food service operators, food industries and manufacturers of frying equipment. The amount of food fried and oils used at both the industrial and commercial levels are vast.

We will start our understanding on this subject by first learning about the deep fat frying process and the factors that influence the process.

Deep-Fat Frying Process

Deep fat frying involves simultaneous heat and mass transfer mechanisms. In addition, the physical properties of the material vary with changing temperature and moisture content. Therefore, theoretical treatment of the process is very complicated and a complete analytical solution to deep-fat frying processes is not available. Several simplified models have been developed, each of which is specified with regard to the material and boundary conditions. Many physical chemical and nutritional changes occur in foods during deep fat frying. Many of these changes are functions of oil temperature and quality, product moisture and oil contents and product residence time in the fryer. Undesirable effects could be minimized and the process could be better controlled if temperature, moisture and oil distributions in food with respect to time could be accurately predicted. In general, the frying process of a single product (french fries, for example) can be divided into four stages that are characterized by the following:

- *Initial Heating*: Short period; submersion of the food in the hot oil; product's surface heated to the boiling temperature of water; natural convection between oil and product's surface; no evaporation.

- *Surface Boiling*: Initial of evaporation; turbulence around the oil surrounding the product; forced convention between product's surface and hot oil; initiation crust formation at the product's surface.
- *Falling Rate:* More internal removal of moisture from the food; rise in internal core temperature to the boiling point; increase of crust layer in thickness; decrease in vapor transfer to the surface.
- *Bubble End Point*: Reduction of the rate of moisture removal; decrease of bubbles leaving from product's surface; continued increase in the crust layer thickness.

The quality of the products from deep fat frying depends on the process conditions and on the type of oils and foods used during the process. The factors that influence the frying process include:

- the temperature of the heated oil, time and the fryer type (batch or continuous).
- the chemical composition of the frying oils, the physical and physico-chemical constants,
- the presence of additives and contaminants. These can have a marked effect on the palatability, digestibility, and metabolic utilization of a fried food, and
- finally, the food weight / frying oil volume and surface area / volume ratios determine how much fat penetrates the food.

12.7 USE OF SALT, SUGAR AND CHEMICALS AS PRESERVATIVES

Salt, sugar and chemicals have been used for ages as preservatives. What is the principle behind their use?

Sugar and salt in concentrated solutions have a high osmotic pressure. When these are sufficient to draw water from microbial cells or prevent normal diffusion of water into these cells, a preservative condition exists. The critical concentration of sugar in water to prevent microbial growth will vary depending upon the type of microorganisms and the presence of other food constituents, but usually 70% sucrose in solution will stop growth of all microorganisms in foods. Less than this concentration may be effective but for short periods of time unless the foods contain acid or they are refrigerated. Salt becomes a preservative when its concentration is increased. Levels of about 18% to 25% in solution generally will prevent all growth of microorganisms in foods. Except in the case of certain briny condiments, however, this level is rarely tolerated in foods.

Chemical food preservatives, on the other hand, are those substances which are added in very low quantities (up to 0.2%) and which do not alter the organoleptic and physico-chemical properties of the foods or only very little. Many chemicals will kill microorganisms or stop their growth, but most of these are not permitted in foods. Preservation of food products containing chemical food preservatives is usually based on the combined or synergistic activities of several additives, intrinsic product parameters (e.g. composition, acidity, water activity) and extrinsic factors (e.g. processing temperature, storage atmosphere and temperature). This approach minimises undesirable changes in product properties and reduces concentration of additives and extent of processing treatments.

The concept of combinations of preservatives and treatments to preserve foods is frequently called the 'hurdle or barrier concept'. Combinations of additives and preservatives systems provide unlimited preservation alternatives for applications in the food products to meet consumer demands for healthy and safe foods.

Chemical food preservatives are applied to foods as direct additives during processing, or develop by themselves during processes such as fermentation. Certain preservatives have been used either accidentally or intentionally for centuries. These include sodium chloride (common salt), sugar, acids, alcohols and components of smoke. In addition to preservation, these compounds contribute to the quality and identity of the products and are applied through processing procedures such as salting, curing, fermentation and smoking.

Usual accepted chemical food preservatives are detailed in Table 12.4.

Table 12.4: Chemical Food Preservatives

Agent	Acceptable Daily intake (mg/Kg body weight)	Commonly used levels (%)
Lactic acid	No limit	No limit
Citric acid	No limit	No limit
Acetic acid	No limit	No limit
Sodium Diacetate	15	0.3-0.5
Sodium benzoate	5	0.03-0.2
Sodium propionate	10	0.1-0.3
Potassium sorbate	25	0.05-0.2
Methyl paraben	10	0.05-0.1
Sodium nitrite	0.2	0.01-0.02
Sulphur dioxide	0.7	0.005-0.2

Some common chemical preservatives used in food products are summarized in Table 12.5.

Table 12.5: Common preservatives in food products

Preservative	Food products
Citric acid	fruit juices; jams; other sugar preserves
Acetic acid	vegetable pickles; other vegetable products
Sodium benzoate	vegetable pickles; preserves; jams; jellies; semi-processed products
Sodium propionate	fruits; vegetables
Potassium sorbate	fruits; vegetables; pickled products; jams, jellies
Methyl paraben	fruit products; pickles; preserves
Sulphur dioxide	fruit juices; dried / dehydrated fruits and vegetables; semi-processed products

Traditional chemical food preservatives and their use in fruit and vegetable processing technologies could be summarized as follows:

1. *Common salt*: brined vegetables
2. *Sugars* (sucrose, glucose, fructose and syrups)

- foods preserved by high sugar concentrations: jellies, preserves, syrups, juice concentrates
- interaction of sugar with other ingredients or processes such as drying and heating
- indirect food preservation by sugar in products where fermentation is important (naturally acidified pickles and sauerkraut).

3. Acidulants and other preservatives formed or added to fruit and vegetable products include:

Lactic acid: This acid is the main product of many food fermentations. It is formed by the 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 moulds 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, moulds. 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) include products such as pickles, sauces and ketchup as can be seen in Table 12.5.

Other acidulants include:

- Malic and tartaric (tartric) acids is used in some countries mainly to acidify and preserve fruit sugar preserves, jams, jellies, etc.
- Citric acid is the main acid found naturally in citrus fruits; it is widely used (in carbonated beverages) and as an acidifying agent of foods, because of its unique flavour properties. It has an unlimited acceptable daily intake and is highly soluble in water. It is a less effective antimicrobial agent than other acids.
- Ascorbic acid or vitamin C, its isomer isoascorbic or erythorbic acid and their salts are highly soluble in water and safe to use in foods.

Commonly used lipophilic (fat loving) acid food preservatives

- *Benzoic acid* in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and jellies, sauerkraut, pickles, preserves, fruit cocktails, etc as highlighted in Table 12.5. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.
- *Sorbic acid is* generally considered non-toxic and is metabolised; among other common food preservatives. The WHO has set the highest acceptable daily intake (25 mg/kg body weight) for sorbic acid. Sorbic acid and its salts are practically tasteless and odourless in foods, when used at reasonable levels (< 0.3 %) and their antimicrobial activity is generally adequate.
- *Sorbates* are used for mould and yeast inhibition in a variety of foods including fruits and vegetables, fruit juices, pickles, sauerkraut, syrups, jellies, jams, preserves, high moisture dehydrated fruits, etc. Potassium sorbate, a white, fluffy powder, is very soluble in water (over 50%) and when added to acid foods, it is hydrolysed to the acid form. Sodium and calcium sorbates also have preservative activities, but their application is limited compared to that for the potassium salt, which is employed because of its stability, general ease of preparation and water solubility.

4. Ga*seous chemical food preservatives*:

a) 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 dissolve in water and at low pH levels 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 is more stable to oxidation than bisulphites, which in turn show greater stability than sulphites.

The antimicrobial action of sulphur dioxide against yeasts, moulds and bacteria is selective, with some species being more resistant than others. *Sulphur dioxide and sulphites* are used in the preservation of a variety of food products. In addition to wines, these include dehydrated/dried fruits and vegetables, fruit juices, acid pickles, syrups, semi-processed fruit products, etc. In addition to its antimicrobial effects, sulphur dioxide is added to foods for its antioxidant and reducing properties, and to prevent enzymatic and non-enzymatic browning reactions.

b) Carbon dioxide: (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. Besides keeping the temperature low, as it sublimes, the gaseous CO_2 inhibits growth of psychrotrophic microorganisms and prevents spoilage of the food (fruits and vegetables, etc.). Carbon dioxide 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 mould 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.

c) Chlorine: The various forms of chlorine constitute the most widely used chemical sanitiser 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-sterilized 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.

While on the topic of chemical preservatives, we must understand that the use of these substances are subjected to certain rules. These general rules for chemical preservatives highlighted below require strict attention.

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 recognized as being without harmful effects on human beings' health and are accepted by national and international standards and legislation.

Next, you will find some general rules/points which you can keep in mind, while using chemical preservatives.

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; they have an antiseptic action on bacteria as well as on yeasts and moulds;
- benzoic acid and its derivatives have a preservative action which is stronger against bacteria than on yeasts and moulds;
- sorbic acid acts on moulds and certain yeast species; in higher dosage levels it acts also on bacteria, except lactic and acetic ones;
- formic acid is more active against yeasts and moulds and less on bacteria.

Remember, while using chemical preservatives, the initial number of micro-organisms 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.

Check your Progress Exercise 4

1. Define deep fat frying as a process of food preparation.

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2. How can the undesirable changes occurring in foods during deep fat frying be minimized?

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3. List the stages of frying process and the factors affecting the frying process.

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4. Explain Barrier concept.

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5. Fill in the blanks:

(i) The substances which are added in very low quantities and do not alter the organoleptic and physico-chemical properties of the foods are ------------------------ .

(ii) -------------, ---------------, --------------, ----------- and -------------- are a few of the chemical food preservatives.

(iii) An acidulant which has an unlimited acceptable daily intake is ---------------------- .

(iv) SO_2 has been used for many centuries as a preservatives because of its -------------------- , ------------------, ----------------------- and -------------------------- .

(v) A general rule to be kept in mind while using chemical preservatives is --------------------- --

12.8 LET US SUM UP

In this unit, we have studied about a few more methods of food processing. Here, we had a detailed discussion on various commonly used as well as commercially employed methods of processing. These included simple and ancient methods such as freezing, fermentation, deep fat frying and use of chemical preservatives to the technologically advanced, recent methods such as microwave heating and irradiation.

Preparation of certain foods involving these processing techniques (fermentation) have been described as well.

After going through this unit, and the previous one, your knowledge on the various food processing techniques must be complete.

12.9 GLOSSARY

Acidulant **:** Food additives that are used to impart a sharp flavor, for instance citric acid.

Air-blast freezing **:** A freezing method, in which high velocity cold air is used to reduce the temperature of the food.

Cabinet Freezing **:** A method of freezing a product by circulation of cold air in a cabinet.

Cryogenic Freezing **:** A fast, flexible and cheap method of freezing in which liquefied gases at an atmosphere below – 60^{o}C, are placed in direct contact with the foods.

Deep fat Frying **:** A process of cooking and drying through contact with hot oil; involves simultaneous heat and mass transfer.

Hurdle or Barrier concept **:** Combination of preservatives and treatments to preservatives and treatments to preserve foods.

Irradiation **:** Use of radiation on food to sterilize food and kill bacteria and control certain factors that cause food spoilage, without making the food itself radioactive.

Sauerkraut **:** Sour cabbage

12.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

(i) slowing down the growth of microorganisms and chemical changes

(ii) a factor of 2-3

(iii) $-1^{o}C$ to $7^{o}C$

(iv) Psychrophillic

(v) type of product, reliable and economic operation, easy cleanability and hygienic design, product quality.

2. Freezing, as a method of food preservation, is the easiest, most convenient and least time-consuming. It does not sterilize foods or destroy the organisms that cause spoilage. Instead the extreme cold simply slows down the microbial growth and the chemical changes that affect quality or cause spoilage.

3. Plate freezing, Immersion Freezing, contact with cooled gas are the different methods of freezing.

4. No, a single freezing system is not enough to satisfy all freezing needs because of a variety of food products and process characteristics.

5. In cryogenic freezing, the food is exposed to an atmosphere below-$60^{o}C$ through direct contact with liquefied or vaporized gases such as N_2 and CO_2. It is a fast method, flexible, has a low capital cost, reduces evaporative weight loss, high product throughput, low floor space requirements, decreases damage due to cell rupture, preserves color, texture, flavor and nutritional value.

Check Your Progress Exercise 2

1.

(i) Electromagnetic waves; 300 MHz and 300 GHz

(ii) Inside out heat penetrates, molecule into the exterior of the product.

(iii) Low , high

(iv) Control organisms that cause foodborne diseases and reduce food losses

(v) Undesirable changes in texture, colour and taste of foods

(vi) Interfere with the cell division.

2. The electromagnetic field of microwaves reacts with water-charged material, an asymmetrically charged material. This reaction leads to the continual change in the alignment of dipolar charge of water, and consequently, production of energy that is converted into heat. This conversion depends on electric field strength, microwave frequency and dielectric properties of the food.

3. The factors that influence microwave heating pattern are: microwave frequency, microwave power and speed of heating, mass of the materials, moisture content, density and temperature.

4. A few advantages of microwave heating over conventional heating are:

- Rapid response, to heat up the reaction mixtures
- The immediate cessation of heat input as soon as the power in turned off.
- Minimal temperature gradients and
- Quick cooling of the unstable products

5. A few potential applications of microwave heating are: baking, curing, blanching, removing solvents, moisture leveling.

6. Irradiation is the use of radiation from gamma rays, X-rays, electron beams or radioactive materials on food.

Check Your Progress Exercise 3

1. Fermented foods are the agricultural products which have been converted by enzymic activities of micro-organisms into desirable food products whose properties are considered more attractive than those of the original raw material.

2. *Idli, Waries, Papadam, Dhokla, Khaman, Kenima, Jalebies, Kurdi, Kanji* are a few fermented foods that are consumed in India.

3. The functions of moulds in the fermentation of foods are: synthesis of enzymes, mould growth, synthesis of coloring compounds and protection of the product

4.

(a) better nutritional value, shelf-life, safer, inexpensive, effective means of food production.

(b) *Monascus purpureus*

(c) 2.5-6.0%.

(d) *Lactobacillus plantarum*

(e) *S. cerevisiae* and *Candida mycoderma*

Check Your Progress Exercise 4

1. Deep fat frying is a process of cooking and drying through contact with hot oil. It involves simultaneous heat and mass transfer.

2. The undesirable changes occurring in foods during deep fat frying can be minimized by predicting the temperature, moisture and oil distribution in foods with respect to time.

3. The stages of frying process are: initial heating, surface boiling, falling rate and bubble end-point. The factors affecting the frying process are as follows:

- Temperature of the heated oil, time and the type of fryer
- Chemical composition of the frying oils, the physical and physico-chemical constants
- Presence of additives and contaminants
- The food weight/ frying oil volume and surface area/volume ratios

4. Barrier concept is the concept of combinations of preservatives and treatments to preserve foods.

5.

(i) chemical preservatives.

(ii) Sodium chloride, sugar, acids, alcohols and components of smoke

(iii) Citric acid

(iv) antimicrobial activity, antioxidant, reducing property, preventing enzymatic and non-enzymatic browning reactions

(v) Any one of the following:

SO_2 and its derivative have an antiseptic action on bacteria, yeasts and moulds.

Benzoic acid and its derivatives have a stronger preservative action on bacteria than on yeasts and moulds.

Sorbic acid acts on moulds and certain yeasts at high dosage, on bacteria except lactic and acetic.

Formic acid more active against yeasts and moulds than bacteria.

Annexure 1

HINTS FOR FREEZING

- Select only fresh, high-quality ingredients because freezing does not improve quality.
- Slightly undercook prepared foods. They will finish cooking when reheated.
- Cool foods quickly before packaging. Place the pan of food in a large pan of ice water, crushed ice or ice cubes. Stirring will help cool the food faster. Use a fan to cool foods that cannot be stirred.
- Freeze food promptly as soon as it is cooled to room temperature.
- Put no more unfrozen food in the freezer than will freeze within 24 hours. Usually this is 2 or 3 pounds per cubic foot of freezer capacity. Stack the food after it is frozen.
- Plan to use frozen prepared foods within a short time. Keep using foods from the freezer and replenish with fresh stock. This makes greater use of freezer space, lowers the cost per pound of food stores, and keeps your store of food fresh.
- The temperature of the freezer should not go above 0 °F. Fluctuating temperatures and temperatures above 0 °F reduce quality.
- Foods that do not freeze well include mayonnaise, cream puddings and fillings, custard, gelatin salads, cheese, the whites of hard-cooked eggs and uncooked egg yolks, and gravies made with wheat flour.
- Since spices may change flavor over long storage, add just before serving.

UNIT 13: PRE AND PRIMARY PROCESSING – SOME BASIC CONCEPTS

Structure

13.1 INTRODUCTION

In the earlier three units, we learnt about the principles and methods of food processing. Certain issues related to production, harvesting and handling of food prior to processing needs to be considered. For instance, how is the raw material (i.e., the food) to be prepared for processing? What are the aspects to be considered while post-harvest handling of fresh foods? What are the primary processing methods used for foods? In this unit, we will focus on these aspects. Production, harvesting, handling and preparation of raw material for processing will be highlighted. All food grains need some kind of processing, say, primary, secondary and tertiary-for bringing them to a palatable state. We will learn about these processing techniques in this unit.

Objectives

After studying this unit, you will be able to:

- know the production and post-harvest handling of fresh produce
- understand why is the preparation of raw materials essential

- describe the concepts of primary and secondary processing of cereals, pulses and oilseeds and
- discuss the concepts of minimally processed fresh foods.

13.2 PRODUCTION, HARVESTING AND HANDLING OF FRESH FOODS

India has made a lot of progress in agriculture since independence in terms of growth in output, yield and area under many crops. It has gone through a green revolution, a white revolution, a yellow revolution and a blue revolution. Today, India is the world's second largest producer of food next to China and has the potential of being the biggest with the food and agricultural sector. India is the largest producer of milk, cashewnuts, coconuts and tea in the world, the second largest producer of wheat, sugar and fish and the third largest producer of tobacco and rice, the second largest producer of fruits and vegetables after Brazil and China respectively.

The present production of fruits and vegetables in India is 47 and 80 million tones respectively. Among fruits, 63% of world production of mangoes, 14% of banana, 8% of pineapple and among vegetables, 12.4% of onion, 6% of potato, 7% of tomato, 13% of cauliflower and 6% of cabbage are produced in India. The per capita availability of food grains has risen in the country from 350 gm in 1951 to about 500 gm per day now despite the increase in population from 350 millions to 1000 millions.

The quality and condition of produce sent to the market and its subsequent selling price are directly affected by the care taken during harvesting and field handling. The objectives of the grower hence should be:

- to harvest a good quality crop in good condition
- to keep the harvested produce in good condition until it is consumed or sold and
- to dispose off the crop to a buyer or through a market as soon as possible after harvest.

To meet these objectives, success in harvesting and marketing must depend on planning from the earliest stages of production.

How to determine whether a crop is ready for harvest or not? What are the factors to be kept in mind that would help to get an optimal yield? What are the environmental conditions best suited for harvesting? Which harvesting techniques should be employed to minimize the extent of wastage? Finally, what post-harvest technologies should be employed to get maximal output as well as reduce the risk of spoilage? In the following sub-sections, we will study about all these aspects.

Let us begin first with the concept of *harvest maturity*, what do we mean by it and what role does it play in the harvesting of crops?

- *When is fresh produce to harvest?*

Optimum quality of fruits and vegetables is obtained only when they are harvested at the optimal stage of maturity. A critical time for growers of fruit and vegetables is the period of decision on when to harvest a crop. Normally, any type of fresh produce is ready for harvest when it has developed to the ideal condition for consumption. This condition is usually referred to as harvest maturity. Harvest maturity refers to *the time when the "fruit" is ready to harvest.*

- *How is harvest maturity identified?*

Before harvesting, the first thing to be looked into is the identification of harvest maturity. We have already seen what the term actually means; let us see how can we identify it. Picking should be done as per maturity indices, which are different for each variety of fruit and vegetable. Most growers decide when to harvest by looking and sampling.

Some of the judgments are based on:

- Number of days from setting
- Sight-colour, size and shape
- Touch-texture, hardness or softness
- Smell-odour or aroma

- Taste-sweetness, sourness, bitterness
- Resonance-sound when tapped.
- Minimum juice content (citrus)
- Break in rind colour (citrus, mango, papaya, pineapple)
- Sugar-acid ratio (citrus, grapes, pineapple)

Experience is the best guide for this kind of assessment. Harvest maturity can be readily observed in some crops: bulb onions, when their green tops collapse and potatoes, when the green tops die off. While other crops can be more difficult: avocados remain unripe off the tree even after maturity.

- *When are conditions right for harvesting a crop?*

When the crop is ready for harvest, will depend largely on weather conditions and the state of the market. When the decision to harvest has been made, the best time of the day must be considered. The aim is to dispatch the produce to market in the best possible condition, that is, as cool as possible, properly packed and free from damage. The basic rules to observe are:

- harvest during the coolest part of the day : early morning or late afternoon;
- do not harvest produce when it is wet from dew or rain. Wet produce will overheat if not well ventilated and it will be more likely to decay. Some produce may be subject to more damage when wet, e.g. oil spotting and rind breakdown in some citrus fruits;
- protect harvested produce in the field by putting it under open-sided shade when transport is not immediately available. Produce left exposed to direct sunlight will get very hot. For example, potatoes left exposed to tropical sunlight for four hours can reach temperatures of almost 50° C.

Produce for the local markets can be harvested early in the morning to avoid higher level of field heat. For more distant markets it may be an advantage-if a suitable transport can be arranged to harvest in the late afternoon and transport to market at night or early the next morning.

- *Harvesting techniques*

Many different harvesting techniques are used depending on the place of sale, the type of crop and the stage of maturity of the crop to be harvested.

In the developing countries, most produce for internal rural and urban markets is harvested by hand where as sophisticated harvesting machinery will be limited for the most part to agro-industrial production of cash crops for processing or export or both. In most circumstances, hand harvesting, picking and catching methods cause less damage than mechanized techniques. Hand-harvesting is usual where fruit or other produce is at various stages of maturity within the crop, that is, where there is need for repeated visits to harvest the crop over a period of time e.g. roots and tuber crops, fruits and vegetables. Machine harvesting is usually viable only when an entire crop is harvested at one time. Machine harvesting may improve quality over manual harvesting.

- *Post-harvest handling of fresh produce*

Fruits and vegetables because of their high moisture content are extremely susceptible to deteriorate, especially under tropical conditions. It is estimated that about 20-30% of the fruits and vegetables produced in India annually (worth Rs. 3000-4000 crores) is lost due to inadequate post-harvest management. These losses result in poor returns to the growers and increase the cost of raw material, which ultimately affects the consumer. Therefore, proper handling of fresh produce after harvesting plays a great role for reducing the losses. Cereals and pulses are relatively stable during transportation and storage due to their low moisture content and hence, less care is usually taken during post-harvest handling except bringing down the moisture content to safe level (usually 12 to 14%) by drying.

At all stages of harvesting and handling of harvested commodities, methods should aim at avoiding damage and loss to the produce. The main steps to be followed during post-harvest handling of harvested food commodities or produce are discussed below.

- *Field processing:* Certain processing techniques at the field itself could help to reduce the chances of spoilage of the fresh produce, specially during transportation. Fruits and vegetables are sorted and graded in the field itself. Also shelling and depodding of peas, beans and lentils can be done in the field. Pre-cooling of the commodity in the field will help in improving the quality and reduce heat build up during transport.

- *Post-harvest treatments:* Certain post-harvest treatments to fruits and vegetables can bring down spoilage significantly. A wide range of chemicals used to control post-harvest diseases include chlorine, sulphur dioxide, dichloran etc. Extension of storage life of fresh produce could be obtained by treatment with skin coatings like wax coating of fresh fruits and vegetables. Treatment of fruits with ethylene or ethylene-releasing chemicals such as ethrel or calcium carbide helps in the induction of early and uniform ripening.

- *Packing and Transportation:* What steps should be taken to minimize the risk of spoilage and wastage of the harvested produce during packing and transportation? What factors need to be considered while transporting these to over long distances? What packing materials should be used? Let us see and try to understand all these aspects.

  Harvested produce should be collected in a suitable container and well packed, and then transported quickly to the destination, without exposing it to the potentially adverse effects of sun, rain or wind. The packing of produce directly into marketing packages in the field at harvest reduces the damage caused by multiple handling and is used increasingly by commercial growers. Most developing countries use traditional baskets, sacks and trays to carry produce to markets. These are usually of low-cost, made from readily available materials such as dried grass, palm leaves or bamboo. They serve the purpose for fresh produce carried over short distances, but they have many disadvantages in big loads carried long distances.

  Farm roads should be kept in good condition for transporting the fresh produce without damage. Containers must be loaded on vehicles carefully and stacked in such a way that they do not shift or collapse, damaging their contents. Vehicles need good shock absorbers and low-pressure tyres and must move with care. At the destination, the produce has to be transferred immediately to the proper storage area depending on the chill characteristics of the product. For long destination, fresh produce may be transported by air or by rail wagon.

Let us now study about how to prepare the raw materials for various processing techniques in the following section.

13.3 PREPARATION OF RAW MATERIALS FOR PROCESSING

All the incoming raw materials, including packaging materials, should be evaluated and monitored to prevent potential contamination of the food product manufactured. Incoming materials must be received into an area, which is separated from processing areas. The raw materials are then processed as soon as possible in order to avoid deterioration. Healthy and sound commodities without any infection are selected for processing. Preliminary preparation of raw materials includes cleaning, peeling, cutting, trimming and grating, sieving, soaking, processing, coating, blanching, marinating, sprouting, fermenting, grinding, drying and filtering.

- *Cleaning:* Cleaning is applicable to vegetables, fruits and many other food products. One of the aspect of cleaning is soaking or washing and is applicable to fruits, vegetables, cereals, pulses and non-vegetarian foods. Washing fruits render them free from dirt, twigs, stalks, sand, soil, insects, pesticides and fertilizer residues. Soaking helps to loosen the adhered soils particularly on root crops. Washing cereals or *dhals* help to remove husk, mud and any other unwanted matter. Hard vegetables are scrubbed under cold running water.
- *Sorting:* The purpose of sorting is to separate the ripe fruits from the underripe or overripe fruits. At the same time, parts of damaged fruits will be removed. Some fruits are cut in two to check the inside.
- *Peeling and stringing:* These methods involve the removal of non-edible or fibrous portion of fruits or vegetables. It may be done (a) by hand ;(b) with steam

or boiling water ;(c) with lye or alkalis (NaOH, KOH) ; and (d) by mechanical means. Peeling facilitates the operation of cutting the raw material into pieces or into slices before processing.

- *Cutting and grating:* Dividing the food into smaller pieces is cutting. This helps in easy cooking. Various terms used under this are cut, chop, mince, dice and slice.
- *Blanching:* Blanching is plunging food commonly fruits and vegetables into boiling liquid and immersing in cold water. This destroys the enzymes present in food which otherwise causes browning and off-flavor hence, used as pre-preparation for preservation. Generally tomatoes, potatoes, almonds, carrots and beans are blanched.
- *Sieving:* Sieving is done to remove coarse fibres and insects and also in preparing cakes for blending of flour with baking powder.
- *Grinding:* The term implies to *reduce to powder by friction, as in a mill, or with the teeth; to crush into small fragment*. This includes both wet and dry grinding. Wet grinding includes the grinding *idli* batter and preparations of *chutneys*. Dry grinding is grinding spices for masala powders and wheat and other cereal grains to flour.
- *Processing:* Processing includes all the things to get food ready for cooking and serving. The various processes included under this are: mixing, blending, binding, beating, whipping, folding, mashing, rolling and stuffing.
- *Marinating:* Marinating is nothing but soaking a food in a *marinade,* which is a seasoned liquid, usually containing an acid, such as vinegar, lemon juice, or wine to add flavour or to tenderize it or both. Vegetables, fruits and meats are marinated with many flavour combinations like oil, flavour and acid. Oil helps to hold natural juices of meat. Acid is used to tenderize by breaking down connective tissue. Vegetables like brinjals, onions, radish, bittergourd, potatoes and chillies are normally marinated.
- *Sprouting or Germination:* It is defined as the process whereby the seeds sprout and begin to grow. All kinds of grams like green gram, bengal gram, peas and cereals like ragi and wheat are generally sprouted. Sprouted pulses are used in making salads and curries.

- *Fermentation:* Fermentation is the process of breaking down of complex matter into simpler ones with the aid of enzymes and bacteria. This can be under aerobic or anaerobic conditions. Fermented foods are often more nutritious than their unfermented counterparts.
- *Drying:* Drying or dehydrating is removal of moisture from food products. Removal of moisture helps to prolong the shelf life of the food.
- *Filtering:* This process is generally done to remove dirt, unwanted particles or to remove moisture from foodstuff. Foodstuffs filtered are coffee, tea, rice, soups, fruit juices and tamarind water.

POINTS TO REMEMBER

1. India is the world's second largest producer of food next to China, and has the potential of being the biggest with the food and agricultural sector.

2. Optimum quality of fruits and vegetables is obtained only when they are harvested at optimal stage of maturity. Harvest maturity refers to the time when the "fruit" is ready to harvest.

3. Maturity indices of fruits and vegetables are determined based on the number of days from setting, sight-colour, size and shape, touch-texture, hardness or softness, Smell-odour or aroma, taste-sweetness, sourness, bitterness

4. When the decision to harvest has been made, the best time of day is during the coolest part of the day: early morning or late afternoon
5. Hand-harvesting is usual where fruit or other produce is at various stages of maturity within the crop, where as machine-harvesting is usually viable only when an entire crop is harvested at one time.
6. It is estimated that about 20-30% of the fruits and vegetables produced in India annually (worth about Rs. 3000-4000 crores) is lost due to inadequate post-harvest management.

7. Fruits and vegetables, because of their high moisture content, are extremely susceptible to deterioration and hence, intense care is taken. Whereas, cereals and pulses are relatively stable during transportation and storage due to their low moisture content and hence, less care is usually taken during post-harvest handling.
8. Pre-cooling of the commodities in the field will help in improving the quality and reduce heat build up during transport.
9. To control post-harvest diseases of fruits and vegetables, chlorine, sulphur dioxide, dichloran are used. To help in the induction of early and uniform ripening of fruits, ethylene or ethylene-releasing chemicals such as ethrel or calcium carbide are used.
10. The packing of produce directly into marketing packages in the field at harvest reduces the damage caused by multiple handling and is used increasingly by commercial growers.
11. Preliminary preparation of raw materials includes cleaning, peeling, cutting, trimming and grating, sieving, soaking, processing, coating, blanching, marinating, sprouting, fermenting, grinding, drying and filtering.

Check Your Progress Exercise 1

1. Fill up the blanks:

(a) India is the largest producer of (i) ……………………in the world, the second largest producer of (ii)……………………………. and the third largest producer of (iii) ………………………………., the second largest producer of (iv)………………………

(b) The objective of the grower should be:

………………………………………………………………………………………

………………………………………………………………………………………

(c) Hand harvesting, picking and catching methods cause……………. than ………………….

(d) …………………of the commodity in the field will help in improving the quality and ………….. heat build up during transport.

(e) The raw materials are processed as soon as possible after harvest in order to avoid ………………….

(f) …………………is a process of heat treatment given to vegetables followed by cooling prior to dehydration or freezing or canning.

(g) …………….. is the process of breaking down of complex matter into simpler ones with the aid of enzymes and bacteria.

2. How is harvest maturity identified?

----

3. When are conditions right for harvesting a crop for local and distance markets?

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4. List the main steps involved during post-harvest handling fresh produce.

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5. What are the preliminary steps involved during preparation of raw materials?

13.4 PRIMARY PROCESSING OF CEREALS, PULSES AND OILSEEDS

Both cereals and pulses are nutritionally important, since both together constitute the staple foods for the population. They are also a relatively cheap source of energy, protein and important vitamins and minerals. All food grains need some kind of processing for bringing them to a palatable state and for their efficient and economic utilization. This is due to the fact that grains contain an outer protective cover of fibrous husk/bran layer.

Cereal grains like rice and maize also contain oil rich bran/germ, which are of high economic value, but are undesirable for the purpose of storage. Separation of these parts from the grains is generally referred to as *primary processing* and is a prerequisite to make them more palatable and safe for storage. The process of preparing certain products like flour, semolina, flakes and popped grains is referred to as *secondary processing*. *Tertiary processing* further processes these to provide variety in product making and to meet the growing demands for ready-to-eat or ready-to- use products.

Let us now have a look at the different levels of processing in a variety of food commodities. We shall begin with cereals-one of the crops that forms a part of the staple diet.

13.4.1 Cereals

Cereals or grains are the seeds of grasses and include the many species of wheat, rice, maize or corn, jowar, barley, ragi, bajra, rye and oats. Cereals account for the largest share, about one-fifth of the consumption expenditure in India. They are mainly consumed in the form of products obtained from primary processing, such as rice from paddy and *atta* or flour from wheat. Rice, wheat, maize and sorghum are the four major cereals, which are grown and consumed in the country. As per FAO figures for the year 2003, India produces around 102 million MT of rice against world's production of 590 million MT.

The ease with which the grains can be produced and stored, together with the relatively low cost and nutritional contribution has resulted in the widespread use of cereal foods.

Processing of Cereals

Owing to the low moisture content, cereals and pulses are relatively stable during storage; and processing is not so much for preservation. However, processing is of primary importance for bringing them to a palatable state, adding a variety to the diet and in improving their nutritive value. They are generally milled to remove the outer husk and the resulting product is consumed after cooking and is used in various food preparations. Cereal processing goes through three stages:

(a) Harvesting: It includes threshing, winnowing and preparation for storage of the cereal grain.

(b) Primary processing: It involves further treatment of the grain such as cleaning, dehulling (decorticating), pounding and milling; and

(c) Secondary processing: It involves transforming the primary processed material into food, i.e., cooking, blending, baking or fermenting and roasting, which makes the grain suitable for human consumption.

The total post harvest system of cereal processing is given in the following flow chart:

Harvesting

↓

Pre-drying in field

↓

Threshing

↓

Winnowing

↓

Drying

↓

Storage

(Sacks, bags, bulk)

↓

Primary Processing

(Cleaning, grading, hulling, pounding, milling)

↓

Secondary Processing

(Cooking, blending, fermentation)

↓

Packaging & Marketing

(a) Let us now take a look at the major steps involved in the post-harvest system of cereals.

(i) Threshing: The process of threshing separates the kernels from the stalks or panicles on which they grow. Threshing may take place in the field, or at the homestead or village; it may be carried out manually with the aid of animals or with machinery. A simple method consists of beating the cereal heads against a wall or the ground; animals or humans can also trample the panicles on a hard surface or animals can draw a machine or sledge over the grain. Maize grains must be separated from the cob after the husk has been removed.

(ii) Grading: Grading consists of separating the sound kernels from chaff and impurities, and may be achieved by sieving or winnowing.

(iii) *Sieving:* Impurities are separated on the basis of their differences in size from the kernels. Hand sieves are usually used singly. The simpler machines will have two sieves: one with oversized holes (which retain large impurities and let the grain kernel pass through) and the other one with undersized holes (which retain the kernels but allow smaller impurities to pass through).

(iv) *Winnowing:* In this process, the impurities are separated on the principle that their density differs from that of the grain kernels. The operation depends on air movement to remove the lighter fractions. The simplest method is to drop a basket of kernels and impurities in a thin stream onto a clean surface through a slight natural breeze. This is a slow and laborious process but it is still widely practiced. Winnowing machines operate on the same principle but a fan creates air movement.

(b) Primary processing of wheat: Wheat is consumed mostly in the form of flour obtained by milling the grain. Wheat can be broadly classified into three groups from the milling and baking point of view: (a) Hard wheat, (b) Durum wheat, and (c) Soft wheat. Flour made from hard wheat is used for bread-making, while flour from soft wheat is used for biscuits, cakes and breakfast foods. Semolina is prepared from hard wheat and durum wheat.

Wheat milling: The milling of wheat consists of the separation of bran and germ from endosperm and reduction of endosperm to fine flour. There are three distinct methods of milling wheat: stone milling, roller milling, and fragmentation milling. Irrespective of the method of milling, all wheat grains will go through two main stages before being milled:
1. ***Cleaning:*** Cleaning of the grain is the main step before milling. The objective is to remove grains of other cereals, seeds from a variety of field weeds, straw, dust and mud from fields, stones, live and dead insects, small rodents and their excreta and small pieces of metal.
The processing stage of cleaning is usually broken down into four separate operations:

- *(a) Screening:* The grain is passed through several sieving operations to remove items both larger and smaller than it. It is then passed along a conveyor belt, where any pieces of metal are removed magnetically and dust, rodent hairs etc. are removed by the use of current air.
- *(b) Sorting:* At this stage, all non-wheat grains such as barley and oats are removed by passing through a range of separators which remove all foreign grains by virtue of their size.

(c) *Scrubbing:* The grain is passed through scanners which remove any mud or dirt and the beard and bee wing from each grain (the bee wing is the epidermis or outer layer of the bran coatings).

(d) *Washing:* This operation cleans the grains by removing any fine dust and hairs, and also any stones, which have not been removed previously. After washing the grain is centrifuged to remove excess surface water.

2. Conditioning: The grain is conditioned to desired moisture content by the addition of water. The purpose of conditioning is to make the bran and germ pliable, thus preventing them from getting powdered. This may be done by moistening the grain and allowed for 24-72 hrs, depending on the air temperature. The cleaned and conditioned wheat is then ready to be milled by one of the following methods:

(i) Stone-milling: The traditional procedure for milling wheat in India has been the stone grinding (chakki) to obtain whole meal flour (atta). In the stone mill, two circular stones are used, each with its surface corrugated radially, with the distance between the stones being smaller towards the outer edge of the stones. In the operation, the cleaned and conditioned grain enters from the above into an aperture in the center of the top stone. The bottom stone is stationery at all times whilst the top one revolves, grinding the grain more finely as it is pushed to the outside of the stones. The resulting flour is then sieved before being bagged. The method results in 90-95% extraction rate flour, which retains almost all the nutrients of the grain, while simultaneously eliminating the part of the grain which is most indigestible, like cellulose and phytic acid, which binds and carries away the minerals.

(ii) Roller-milling: The roller-milling is a much more complete method than stone-milling and involves a large amount of specialized equipment. It is concerned with the milling of white flour, where bran and germ are separated from endosperm and flour of any extraction rate can be produced. The process can be broken down into two clear stages:

- *Breaking:* The cleaned and conditioned grain is passed through a series of break rolls. These are the grooved rollers, which operate in pairs, rotating in the opposite direction to each other, the top one rotating two and a half times faster than the lower roller. It is usual for the mill to have five sets of break rolls, with each set being more finely set than the previous set of break rolls. Each of the above are passed through purifiers, where by means of air currents any minute particles of bran are removed to ensure purity of the white flour end-product.

- *Reduction:* The purpose of this stage is to reduce the endosperm to fine flour and to extract the germ. The reduction stage is less complicated than the breaking stage. It consists of a series of reduction rollers, which are smooth and each pair is set more finely than the previous set. After passing through each set of reduction roller, the product is sieved; the coarse particles go to the next set of rollers for finer reduction. The process is repeated until all the semolina, which was fed into the reduction rollers, is reduced to fine white flour, germ and a small amount of branny by-product. The germ is extracted early in the reduction stage, where it is easily sifted off because being of a tough and oily nature, it is flattened on the rolls with little fragmentation taking place.

(iii) Fragmentation-milling (Air classification): This is a relatively new method of milling, by which it is possible to control the protein quality and quantity in the production of a particular flour. This is a refinement of roller-milling in that after producing the white flour, it is then processed a further step and is separated by means of air classification into particles of three broad ranges, lesser the size, higher the protein content.

Primary processing of Rice

Rice is the staple food for the majority of the world's population and is cooked in boiling water and eaten mostly with cooked pulses, vegetables, fish or meat. It is also used in many food preparations like idli and dosa. Rice with the husk is called *paddy*. Primary processing of rice consists of cleaning, grading, dehusking (shelling) and milling (polishing). Dehusking and polishing are traditionally accomplished by hand pounding, using pestle and mortar. In modern rice milling, the two main steps involved are dehusking and polishing.

(i) Cleaning and grading: The paddy as received will contain foreign matter such as stones, clay particles, straw, chaff and dirt. These have to be separated in a paddy cleaner.

(ii) Dehusking (shelling): After cleaning, the outer husk is first removed by shelling process exposing the grain covered by a brown bran layer. It is sold in this condition as brown rice. The shelling is carried out normally using two different types of shellers:

(a) *Disc sheller:* It consists of two discs. The inside surface of the discs is covered with a mixture of emery and hard cement. The clearance between the discs is adjusted close to the length of the paddy grain to be shelled. One plate is stationary, while the second plate revolves. The husk is removed by aspiration.

(b) *Roller type Sheller:* It consists of two horizontally set rubber rollers rotating in opposite directions, the differential rotation between the two being kept at about 200 per min. Dehusking is effected by the grain hitting the rotating rollers. The resulting brown rice contains the pericarp and germ almost intact. The breakage of rice is minimum with this machine.

(iii) Rice milling (polishing): The brown rice obtained by shelling can be milled (polished) further in a stage known as "pearling" using either a cone-type polisher or a horizontal-type polisher to remove the coarse outer layers of bran and germ, leaving a white grain. Sometimes, the polished rice is further treated with mineral substances such as talc or sugar to give the grain a bright shining surface.

Subsequently, a simple machine like huller came into existence. Hullers achieve both dehusking and polishing in one step. It is estimated that there are over 1, 30,000 hullers in operation throughout the country. They are largely located in the rural areas. More than 30% of paddy produced is processed in hullers.

(iv) Parboiled rice: Parboiling is an ancient process of India. More than 50% of paddy produced in the country is parboiled. Parboiling means *partial boiling and cooking of rice in a limited water environment.* For this reason, prior to milling, the paddy is fully soaked in water and then the drained paddy is cooked by steaming or by dry heat. The process

gelatinizes the starch in the grain aiding the retention of much of the natural vitamin and mineral content. Surprisingly, parboiled rice takes longer to cook, but has the advantage of taking up more water during cooking and therefore increasing the yield.

(v) By-products of rice: The important by-products obtained in rice milling are rice bran oil, bran or polishing (good source of protein and fat), husk (fuel, insulating material, paper making, production of furfural).

(vi) Rice products: Of the 100 million tones of paddy, about 10% is converted to various products like flaked rice (*Aval, Chewda* or beaten rice), expanded rice (*Puri, Murmura*) and popped rice (*Aralu, Kheel*). The other rice products are instant rice (quick cooking rice), rice flour, rice starch etc.

Processing of minor cereals

Maize, jowar, bajra, ragi and other small millets are important minor cereals of our country. They are also termed as *coarse grains*. They are widely consumed without much refinement by the poorer sections of the population, particularly in the rural areas. Judicious refining of these grains can upgrade their appearance and eating quality by removal of the unpalatable rough bran layers without affecting their nutritive quality.

Traditional milling of these grains is done by pounding in a mortar and pestle to remove the outer bran. Dry and slightly wet (soaked in water to soften the bran) and tempered grains are used. After pounding, the bran is removed by winnowing and the endosperm is ground in the same unit or small mechanical hammer/plate mills. Pounding is a very laborious and time-consuming operation and also the quality of the product is often not very good because of high moisture content of the flour and mixing of ground bran. In the mid sixties, it has been observed that when 3-5% water was mixed with the grains and tempered for 5-15 minutes, the outer bran layers were sufficiently toughened and could be abraded off (without powdering) in simple abrasive rice polishers (pearlers) without affecting the inner grain portion, which remained hard. This pearling technique has been applied successfully to jowar, bajra, varagu and wheat. The pearled grains find wide use for traditional preparations like roti, bhakri, bhath etc.

13.4.2 PULSES

Pulses are the edible fruit or seed of pod-bearing plants and are widely grown throughout the world. They have a high protein content ranging from 20-40%, which makes them important as a major source of proteins in the diets of population dependent mainly on cereals as staple foods around the world. Economically, they provide reasonably good quality protein at a fraction of the cost of animal proteins. In most of the parts of the world, pulses are traditionally consumed either in the whole or in the dehulled split form, as soft-cooked products. Almost all pulses are grown in India. Red gram or *tur* (*arhar* or pigeon pea), Bengal gram or chick-pea (*chana*), Black gram or *urad* and Green gram or *mung* are considered as major pulses depending on their production and consumption while *moth* or tepary bean, lentil, horsegram or kulthi, peas, khesari dhal and others (cow pea, cluster bean or guar, French bean or kidney bean, Indian bean or field bean and soybean) etc. are known as *minor pulses,* since they are grown and consumed only in certain regions. Many of the pulses contain toxic factors, which cause many diseases in human. The toxic factors can be eliminated either by heat processing or by leaching them out in boiling water.

Primary processing of pulses

Dry pulse seeds have a tight and fibrous seed coat (husk or skin) that envelops the cotyledons, which often is indigestible and may have a bitter taste. In grains like cowpea and green gram, the seed coat is thin forming 8-10% of the grain, whereas in Bengal gram and *tur*, they are thick and constitute 10-14% of the grain. Primary processing of pulses involves cleaning, removal of husk or skin and splitting.

Pulse Milling

Milling of pulses consists of 2 steps: loosening the husk and its removal followed by splitting into dhal. Loosening of the husk referred to as “pre-milling treatment” is normally achieved by wet or dry method, which involves intermittent sun-drying after the application of oil and water. Dehusking or dehulling or milling and splitting are done in chakkies or power driven machines. Milling is usually done by two methods:

(a) Wet process:

The wet process has been commonly used with pigeon pea or red gram, as the skin in this grain is difficult to be removed. The process consists of the following steps: (i) soaking the grain in water overnight, (ii) smearing the soaked grain with red earth mixed with water and keeping the grain moist as a heap by sprinkling water for 16-24 hours, (iii) drying the grain in sun, and (iv) dehusking the grain using granite or wooden hullers.

(b) Dry process after conditioning skin with water or oil:

(i) Dry process after conditioning skin with water-chickpea, lentils, lathyrus, pea and dried peas.

(ii) Dry process after conditioning skin with oil-pigeon pea or red gram, black gram and green gram

In the first process, the grains are cleaned and after an initial scouring or pitting operation in roller mills, they are sprayed with water 5-10% by weight of the grain and kept in a closed vessel for the water to be fully absorbed by the skin. The material is then dried in the sun. Similarly, in the second process, the cleaned and pitted grains are treated with a vegetable oil (0.2 to 0.5%). The grains are dried in the sun and then conditioned by spraying water (about 4-5%). The conditioned grains are again dried in the sun.

In both the pre-milling treatments, adherence of the husk to the cotyledon weakens and consequently, its removal becomes easy.

The loosened seed coat of the pretreated pulses is then removed in the subsequent operation of milling. For this purpose, different machines are used depending on the types of pulses and scale of operation. Pulse milling is practiced at different levels, viz, (a) home scale, (b) cottage scale, and (c) large scale level and machines like pestle and mortar, hand-driven chakki are used in home-scale and roller mill in cottage and large-scale operation. There is much loss due to powdering and /or breakage. This process is dependent on climatic conditions, laborious and does not give more than 70% of dehusked and split grains although higher yields are possible.

Pulse products:

The important processed pulse products are puffed chickpea and pea, *besan*, papads, pulse-based weaning foods, quick cooking *dhals*, and canned dry peas

13.4.3 Oilseeds

Like pulses, oilseeds and nuts are rich in protein and in addition, they contain a high level of fat. At present, India accounts for 9.6% of world's total output of oilseeds. The major oilseeds produced in the country include groundnut, rapeseed/mustard, castor seeds, sesamum, nigerseed, linseed, safflower, sunflower and soybean. However, groundnut, rapeseed/mustard and soybean accounts for a major chunk of the output.

Primary processing of oilseeds

Oilseeds are the major sources of edible oil. Edible oilseed meals (cakes) obtained from oilseeds are often highly nutritious and can be used for either animal or human food. The residual oilcake has been used for the preparation of protein foods for feeding the infants and preschool children in developing countries.

There are four main steps involved in the preparation of oil and edible meal from oilseeds:

1. Preparation of the raw material
2. Oil Extraction
3. Clarification
4. Packaging and storage

Let us discuss these one by one.

1. Raw material preparation: This involves cleaning and dehusking. Some raw oilseeds have a fibrous husk or seed coat, and this must be removed prior to processing. The removal is known as *decortications* and a range of decorticating machines are available which are suitable for small-scale production. The separation of the husks or seed coat from the oil-bearing material after decortications is achieved by gently throwing the seeds into the air and letting the air blow away the husks. This method is called as *winnowing* and requires skill and experience. Some of the oilseeds require grinding or flaking. Traditional hand-pounding methods using a pestle and mortar or more sophisticated roller mills, may be employed to grind groundnuts into coarse flour. Flakers are used for sunflower seeds, and hammer mills are applicable for palm kernels. Subsequently, some of the grounded oilseeds such as groundnuts and sunflower are conditioned with addition of 10% water followed by heating to 90° C in order to rupture the oil-bearing cells. The heating is traditionally carried out over open fires, although seed scorchers, which are basically pans fitted with stirrers, are now available to mix the seeds better.

2. Oil extraction: Extraction of oil from the prepared oilseeds can be done by one of the following methods: (i) traditional method: *ghani*, (ii) Improved methods: (a) mechanical pressing (hydraulic pressing), (b) screw pressing (expeller pressing), (c) prepress solvent extraction, and (d) direct solvent extraction. Let us study about these methods:

(i) *Ghani:* It originated in India, but their use is now more widespread. A ghani consists of a wooden mortar and pestle. The mortar is fixed to the ground, and the pestle is located in the mortar, where the raw material is crushed by friction and pressure. An animal is required to move the pestle and as this continues the oil is pressed out, runs through a hole at the bottom of the mortar, and the residue (cake) is then scooped out. Ghanis are limited in that two animals are required, since any one animal will tire after 3-4 hours. Motorized ghanis are becoming increasingly popular and are fast replacing animal-powered equipment. Mustard oil, groundnut oil and sesame oil are traditionally produced by this method.

*(a) Hydraulic pressing**:*** Prepared raw materials to be crushed are placed in heavy perforated or slotted metal cages (12 to 16 Nos.) and a metal plunger is used to press out the oil. The maximum pressure applied is

2000 psi for a period of 20-50 minutes. The oil content of the press cake may vary from 5 to 8% depending on the raw material.

(b) *Expeller pressing (screw pressing):* The raw material is continuously fed to the expeller, which grinds, crushes, and presses out the oil as it passes through the machine. Oil flows through the perforations in the casing and is collected underneath. The residue, or oilcake, is pushed out of the end of the unit Most small expellers are power-driven. The oil content of the press cake after second pressing may vary from 5 to 8%.

(c) *Prepress solvent extraction:* In this process, the oil from the raw material is expressed in a screw press by single pressing and then the residual oil from the press cake is solvent-extracted by using food grade hexane followed by desolventization of the material. The protein quality in the meal obtained by this method is not adversely affected.

(d) *Direct solvent extraction:* This process is used for the oilseeds having low fat content e.g., soybean. The process consists of the following steps: (i) cooking of the material in steam and flaking, (ii) solvent extraction of the flakes using food grade hexane, and (iii) desolventizing the meal.

3. Clarification of oil: Crude oil contains a suspension of fine pulp and fibre from the plant material. It also contains smaller quantities of water, resins, colors and bacteria, which makes it darker in colour. These contaminants are removed by clarifying the oil, either by allowing the oil to stand undisturbed for a few days and then removing the upper layer, or by using a clarifier. If further clarification is needed, the oil may be filtered through a plastic funnel, which has been fitted with a fine filter cloth. Finally, the oil is heated to boil off the traces of water and destroy any bacteria. For those raw materials, which are processed wet (such as coconut), heating is applied prior to clarification in order to break the emulsion. When these impurities are removed, the shelf-life of the oil can be extended from a few days to several months, provided it is stored properly.

4. Packaging and storage of oil: Rancidity can cause the oil to deteriorate and develop off-flavors during storage. Using clean, dry containers, which exclude light and heat, and prevent contact with metals such as iron or copper, may prevent this. Sealed glass or plastic bottles are adequate packaging materials. The containers should be properly dried after cleaning to remove all traces of water. If the oil is packaged adequately and kept away from heat and sunlight, the shelf-life can be expected to be 6-12 months.

13.4.4 Minimally processed fresh foods

Today's consumers are increasingly demanding convenient, ready-to-use and ready-to-eat foods with a fresh like quality, and containing only natural ingredients. The concept of minimal processing theoretically involves the care of foods throughout the entire post-harvest system - from the farm-gate all the way to the consumer, while also meeting the demands of the consumer for convenience and fresh. This minimal processing approach is also called as *hurdle technology*, simply because a series of hurdles is placed in the way of the micro-organisms growth and survival; e.g. combinations of weak acid treatments with modified atmosphere packaging or mild heating with reduced water activity, or alternative doses of mild heating and chilling.

Minimally processed foods include conventional products such as prepared vegetables and salads, prepared fruits, prepared meat items, heat-and-eat meals and new generation foods such as fresh pasta and pasta sauces. If these products are heat processed, the heat treatment is much less than that required of the canned foods. Chilled ready-to-eat or ready-to-heat foods are a very rapidly growing segment of the market. Some of the best examples of this are the fresh and sliced apples and potatoes packaged under the modified atmosphere packaging that have a shelf-life of three weeks. These products are prepared under very rigorous hygienic conditions, packed under vacuum and cooked at fairly low temperatures.

The advantages of minimally processed foods are many:

- Maintains freshness and quality;

- Renders fruits and vegetables in convenient and ready-to-cook form;
- Extends the shelf-life;
- Bulk reduction for better storage, easy transportation and packaging;
- Boosts export of vegetable in minimally processed form;
- Renders 60% value addition; and
- Low technology, without involvement of sophisticated machinery.

Increased product safety is also much in demand by the producers and distributors. The fresh-like products are highly perishable and actions that increase safety are important. Minimally processed products readily deteriorate in quality than the original raw material due to the alteration of tissue integrity during processing of these products. Therefore, minimally processed foods must be held continuously at refrigerated temperatures and guarded from temperature abuse in distribution and retailing.

POINTS TO REMEMBER

1. *Major cereals:* Rice, Wheat, and Sorghum; *Minor cereals:* Maize, Jowar, Bajra, Ragi and other small millets.

2. *Major pulses:* Black gram or urad, peas, Green gram or mung, Bengal gram and Soybean. *Minor pulses:* Moth or tepary bean, lentil, horsegram or kulthi, khesari dhal, cow pea, cluster bean or guar, French bean or kidney bean.

3. The important oilseeds are groundnut, rapeseed/mustard, castor seeds, sesamum, nigerseed, linseed, safflower, sunflower and soybean.

4. All foodgrains need some kind of processing for bringing them to a palatable state, and for their efficient and economic utilization.

5. Processing of cereals consists of three stages: harvesting, primary processing and secondary processing.

6. The milling of wheat consists of: separation of bran and germ from endosperm and reduction of endosperm to fine flour. It involves three stages: cleaning, conditioning and milling.

7. Primary processing of rice (paddy) consist of cleaning, grading, dehusking (shelling) and milling (polishing).

8. The important by-products obtained in rice milling are rice bran oil, bran or polishing (good source of protein and fat), husk (fuel, insulating material, paper making, production of furfural).

9. Primary processing of pulses involves cleaning, removal of husk or skin and splitting.

10. Using clean, dry containers, which exclude light and heat, and preventing contact with metals such as iron or copper, can eliminate rancidity in oil during storage.

11. Minimally processed foods are convenient, ready-to-use and ready-to-eat foods with a fresh like quality, and containing only natural ingredients e.g. prepared fruits, vegetables, salads, meat items, heat-and-eat meals, fresh pasta and pasta sauces.

Check Your Progress Exercise 2

1. Mention the different methods of wheat milling.

   ----

2. List the important rice products.

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3. Mention one advantage of parboiling of rice.

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4. Write the purposes of conditioning of wheat prior to milling.

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5. What are the important processed pulse products?

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6. What are the steps involved in pulse milling?

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7. List the main steps involved in the preparation of oil from oilseeds.

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8. List the methods of oil extraction.

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9. What are the impacts of minimally processed foods?

13.5 LET US SUM UP

In this unit, we studied about issues related to production, harvesting and handling of food prior to processing.

Availability of raw materials is another important consideration for processing. We learnt about the present scenario of production of agricultural produce like cereals, pulses, fruits and vegetables, milk, sugar, fish etc. in India. We also discussed the importance of right type of harvesting procedures in order to maintain the quality as well as to minimize the wastage of fresh produce during post-harvest handling including transportation.

In another section, we learnt about the various steps involved during preliminary preparation of raw materials prior to processing or to produce finished products. The important steps are cleaning, washing, sorting, grading, peeling, trimming, blanching, etc. Though the cereals, pulses and oilseeds are relatively shelf-stable commodities due to low moisture content, they need to be processed to bring them to a palatable state and in improving their nutritive value. In this regards, we have studied the various primary-processing steps involved in cereals and pulses milling and in oil extraction.

There is a growing demand for ready to use and ready to eat foods with a fresh like quality in the consumers' market. In this connection, we studied the concept of preparation of minimally processed fresh food like fruits and vegetables, meats etc. Since the fresh like products are highly perishable and actions that increase safety are important.

13.6 GLOSSARY

Acetic acid : active ingredient in vinegar; used in food preservation.

Acid foods : foods which contain enough acid to result in a pH of 4.5 or lower. Includes all fruits except figs; most tomatoes; fermented and pickled vegetables; relishes; and jams, jellies and marmalades.

Anaerobic fermentation : fermentation in the absence of air (secondary fermentation).

Antioxidants : scavengers of particles called oxygen-free radicals.

Asepsis : keeping out microorganisms from food.

Blanching : process of exposing a food product to either steam or hot water for a short time, before being placed in packages and frozen or dried.

Canning : method of preserving food in air-tight vacuum-containers and heat processing sufficiently to preserve the food.

Clarifier : a chemical used to help clear water by coagulating smaller particles into filterable sizes.

Contaminant : an undesirable substance that is considered to make something impure or dirty.

Curing : a method of food preservation that involves soaking the food in a strong salt solution.

Decortication : removal of the outer covering of an organ or part.

Dehydrating : method of food preservation that involves removing the water from the food.

Emulsifier : A substance that is used to prevent the liquids in an emulsion from separating into layers.

Food additive : a substance added to food that enhance the palatability or preserve the foods.

Food spoilage : a process which occurs due to growth of microorganisms, action of enzymes present in the food, mechanical and insect damage to the food.

Freezer : a reach-in or walk-in food storage unit that maintains a temperature of 0°F (-18° C).

Freezing : a method of food preservation involving low temperatures (-18° C), a change of state of a substance from liquid to solid.

Hermetic seal : an absolutely airtight container seal, which prevents reentry of air or microorganisms into packaged foods.

Marinating : a form of food preparation; it involves leaving the food for a given time while it is coated in a liquid. The process makes the food tastier, easier to chew and digest, and sometimes it is used as a preparation before other forms of cooking.

Oxidation **:** reaction with the oxygen in the air, causes food to go bad.

Par-boiling **:** partial boiling or cooking of rice in a limited water environment.

Pasteurization **:** a heating process designed to destroy the most heat-resistant pathogenic or disease-causing microorganism in a food product.

Perishable Food **:** a food product that spoils readily without special processing or preservation techniques.

Pickling **:** the practice of adding enough vinegar or lemon juice to a low-acid food to lower its pH to 4.6 or lower.

Pounding **:** repeated heavy blows.

Preservative **:** a substance used to prolong the shelf life of foods or to prevent the spoilage of food.

Rancidity **:** development of any off or disagreeable flavors in oil or fat due to enzymatic or oxidative reactions.

Sprouting **:** the process whereby the seeds or spores sprout and begin to grow.

Staple food **:** a basic but nutritious food that forms the basis of a traditional diet, particularly that of the poor.

Sterilization **:** a process that destroys virtually all microorganisms and their spores.

13.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

(a) (i) Milk, cashewnuts, coconuts and tea; (ii) wheat, sugar and fish; (iii) tobacco and rice; (iv) fruits and vegetables.

(b) (i) to harvest a good quality crop in good condition; (ii) to keep the harvested produce in good condition until it is consumed or sold; (iii) to dispose of the crop to a buyer or through a market as soon as possible after harvest.

(c) less damage ; mechanized techniques

(d) Pre-cooling; reduce

(e) Deterioration

(f) Blanching

(g) Fermentation

2. Maturity indices can be determined on the basis of : Number of days from setting, Sight-colour, size and shape, Touch-texture, hardness or softness, Smell-odour or aroma, Taste-sweetness, sourness, bitterness, Resonance-sound when tapped, Minimum juice content, Sugar-acid ratio.

3. The conditions right for harvesting a crop for local markets: harvest in the early morning to avoid higher level of field heat while for the distant markets: harvest in the late afternoon and transport to market at night or early the next morning.

4. Main steps involved during post-harvest handling fresh produce are:
   Field processing: sorting, grading, shelling and depodding, pre-cooling.
   Post-harvest treatments: treatments for controlling disease, for enhancing or delaying ripening, skin coating
   Packing and Transportation: packing in suitable container to prevent damage and from spoilage during transportation.

5. Preliminary steps involved during preparation of raw materials include cleaning, peeling, cutting, trimming and grating, sieving, soaking, processing, coating, blanching, marinating, sprouting, fermenting, grinding, drying and filtering.

Check Your Progress Exercise 2

1. Three methods of wheat milling are stone milling, roller milling and fragmentation milling.

2. The important rice products are flaked rice, expanded rice, popped rice, instant rice, rice flour, rice starch etc.

3. The advantage of parboiling of rice is to retain natural vitamin and mineral content in the rice.

4. The purpose of conditioning of wheat prior to milling are to make the bran and germ pliable, thus preventing them from getting powdered during breaking.

5. Puffed chickpea and pea, *besan*, papads, pulse-based weaning foods, quick cooking *dhals*, and canned dry peas are the important processed pulse products.

6. The important steps involved in pulse milling are - overnight soaking in water, smearing with red earth mixed with water followed by sprinkling water for 16-24 hours, sun dried, dehusking and splitting.

7. The main steps involved in the preparation of oil from oilseeds are: preparation of the raw material, extraction, clarification, packaging and storage.

8. The methods of oil extraction are: (i) traditional method (ghani); (ii) improved methods, such as hydraulic pressing, screw pressing, prepress solvent extraction and direct solvent extraction.

9. Impacts of minimally processed foods are: it maintains freshness and quality; convenient and ready-to-cook form products; extended shelf-life; bulk reduction for better storage, easy transportation and packaging; boosts export potential; about 60% value addition; low technology, without involvement of sophisticated machinery.

UNIT 14: PRODUCT DEVELOPMENT AND EVALUATION

Structure

14.1 INTRODUCTION

In India processed food is gaining importance as "commercial commodity". It becomes more evident when we see the wide range of packaged food products available in the market. Increase in popularity of processed foods can be traced to several causative factors: growing urbanization, changes in lifestyle, increasing number of nuclear families, working women and the purchasing power. Food industry in India is broadening its product range in response to emergence of wider clientele range. The industry has to cope with the competition from the multinational companies who are launching new products at regular intervals. In such a situation, the food manufacturers have to be watchful not only about maintaining and improving the quality of their products in the market but also about developing new products. These new products shall have advantages such as offering convenience, better nutritive value, health benefit, superior sensory quality and cost effectiveness. Developmental work in food industry is a continuous process beset with challenges. This unit will cover important areas of product development and evaluation.

Objectives

After studying this unit you will be able to:

- explain why is it necessary to develop new products
- describe what are the factors responsible for development of new products
- appreciate the role of sensory evaluation at different stages of product development
- assess consumer acceptability
- describe what are functional foods
- discuss the ingredients providing health benefits and their use in specialty foods and
- determine shelf life studies

14.2 NEED FOR PRODUCT DEVELOPMENT

In the present market scenario of processed foods we observe that sales profile of established brand names undergo unpredictable fluctuations. In a few instances, the once popular product may lose its premium position in the market. Therefore, the manufacturer should evolve effective strategies to achieve and to retain a well secured place in the market. One such strategy is to introduce new products having better consumer appeal. So now in this context, let us first understand what we mean by product development?

Product development is by definition a future-oriented practice. It is an effort to foresee the future needs of the market place and to translate this information into state-of-the-art products.

In order to develop a new product, the manufacturer should have the knowledge about all the factors influencing the development of new products. So then let us learn about these influencing factors.

14.2.1 Factors Influencing Product Development

Product development is an innovative activity designed to meet the changing consumer demands. It is becoming increasingly important in the dynamics of marketing environment. Product developers should be familiar with marketing, financial implications and logistics of introducing a new product into the competitive market. Moreover, they have to know how to undertake product development work from the customer's perspective. Products will have to be developed in response to a specific, clearly identified market opportunities. In addition to consumer demands, the driving forces behind new product development are peer competition, availability of new technology and alternate raw materials, and desire for novelty. Market fragmentation leads to developing different types of foods for various categories of consumers. As these are likely to intensify, the product life cycles are likely to shorten. Increase in the purchase power of sections of population, changing life styles, and increased emphasis on health and nutrition put pressure on processors to offer something new to the consumer. Science and technology in the food industry are increasingly defined by the demands and perception of the market place. To cope with such a situation the food industry has to resort to product development and innovation as a continuous activity.

But, whatever may be the influencing force, remember it is always important to develop consumer oriented products. And how do we go about it? Read and find out.

14.2.2 Consumer Oriented Product Development

It is important that new product development strategies are adjusted to identified needs in the market. This requires an appropriate methodology to translate consumers' choice or expectations into identifiable quality characteristics. Once this concept is formed it will be possible to provide detailed guidance for product development. Consumer oriented approach consists of five steps:

1. Identify the opportunity for new product

2. Design of the new product
3. Market testing of the new product
4. Launching the product in identified markets and
5. Life – cycle management.

Opportunity identification stage concerns the definition of the best market segment to introduce the new product, and the generation of new product ideas.

At the product design phase the plan of action is :

1. To identify the key benefits the product is to provide to the consumer
2. Positioning of these benefits versus competitive products and
3. Development of the product and marketing strategy.

Purchasing pattern of the consumer, what they consider important in their choice behaviour and what they consider short – comings in present product supply provide insight into some basic issues of product development. Consumer perception and preference have to be carefully studied while formulating a new product. Market testing may involve segmentation to identify relevant subgroups of consumers that are homogeneous in terms of preference and purchasing behaviour. If the new product is promising, as judged by the testing, it is ready for commercial sale.

With our understanding of the concept of product development and the factors which influence it, let us now learn the process i.e. the methodology of product development.

14.3 HOW TO DEVELOP A NEW PRODUCT

The process of developing a new product comprises three phases, namely formulation or recipe development, standardization of processing methods, and evaluation and testing of quality parameters of the final product.

The critical issues here are:

(i) to find out the optimised recipe,

(ii) to evolve effective processing conditions

(iii) to ensure food products of high quality and

(iv) to accurately predict marketability.

It is well known that most of the food products contain a variety of ingredients and preparing the product involves several processing steps. So, while working on a new product one has to study whether the recipes and methods of processing can yield an acceptable product, or is there a need for modifying them to improve the quality and to meet the demands of the market. The three phases of product development, you learnt about earlier, are interrelated and any changes that are made in implementation of one phase, will affect other two phases. Therefore, the task of planning the work becomes complicated. The simplest methodology, therefore, in product development is adopting *one – factor – at – a time method* which is also known as *trial and error method*. It is a simple method in which if changes are to be made in the formulation, only one of the ingredients can be changed at time. For example flavourings, salt, and sugar are the ingredients used in the preparation of sweet and spicy varieties of fried snacks. These are considered as the variables which influence the product quality. Affect of flavourings is tested by varying its level while maintaining constant salt and sugar levels. The product with optimal quality is selected. The optimal salt and sugar levels are then determined in a similar way. The optimal levels of flavourings, salt and sugar are then combined in the preparation of the sweet and spicy fried snack which will have the overall optimum quality. The trial and error method has been in use for along time. But this optimization method has certain disadvantages:

1. It is laborious and time consuming
2. It does not provide information about variable interaction effects, and
3. Achieved optimum consists only one variable levels that are actually tested. This could lead an inexperienced product developer to unreliable or false optimal results. In the above example, the change in salt and / or flavourings levels would probably modify the optimal salt level. Because of these possibilities the " overall optimum' achieved might not be the true optimum.

Considering these drawbacks, more effective methods have been introduced in the field of new product development, which are highlighted now.

14.3.1 Statistical Experimental Methods

Statistical experimental methods are used in product development. In order to adopt the statistical product design or experimental method, it is necessary to understand the basic concepts and terms. Important ones among these include:

1. *Independent variables* also known as factors are the parameters or characteristics, including ingredients and processing conditions, which have an effect on product quality. Independent variables can be varied. Amount or type of ingredients, temperature and time of processing and moisture content are examples of common factors in food production.
2. *Dependent variables*, or the responses are the important measurable food quality indices. These are influenced directly or indirectly by different factors. Some examples of responses are sensory quality, nutritional value, chemical composition, microbiological characteristics and shelf – life.
3. *Test levels* or levels are the quantity of factors selected to be tested in the experimental design. A combination of factor levels is chosen according the experimental design.
4. A *model* is a mathematical equation that describes the relationship between the response values and different factors quantitatively. It can predict optimized combination of factors to obtain products having required quality.

While dealing with the experimental design method, different kinds of system problems are encountered. These are discussed next.

A. Product process problem

In food product design, there are two different kinds of system problems – process and mixture problems – that should be dealt with by different statistical experimental methodologies.

In the process problem, all the independent variables are not related to each other but are *orthogonal* to each other. The change of one variable is not restricted by another variable. Geometrically, the lines representing these variables meet at right angles. In bread making for example, the temperature of the baking oven can, in principle, be chosen without any influence on the setting of baking time. Of course, only suitable settings of oven temperature and baking time can lead to desired bread baking results. To solve a process problem, the statistical experimental designs used should contain no or few correlations between the independent variables, so that their natural or original properties of "independence" can be retained. These kinds of statistical experimental designs are usually factorial experimental designs or designs derived from it.

B. Recipe problem

Recipe is one of the most important factors leading to successful food products. A recipe usually includes several ingredients, which have different effects on specific food quality. To study these effects is the prerequisite for being able to choose the optimal recipes.

Many food products are manufactured by mixing two or more ingredients. In bread and cake formulations, for example, flour, sugar, baking powder, shortening, and water are used. In this case, one or more properties of the food product generally depend only on the proportions of the ingredients present in the mixture and not on the amount of the mixture. One ingredient (an independent variable) cannot vary without changing at least one of the other ingredients in the mixture, because all the ingredients will be part of a constant sum of 100%. In other words, the variables or the ratios of different ingredients in the recipe are dependent on each other. These phenomena do not meet the orthogonality requirement of a conventional factorial design. Therefore, to study and model the effects that different ingredient components in a mixture have on the food product properties of interest, the factorial experimental design is no longer suitable unless it is modified. The effect of ingredient components (mixture variables) on food quality (response) are modeled differently from those effects based on the usual factorial experimental methodology.

As described above, the distinguishing feature of a mixture problem is that the independent or controllable factors represent proportionate amounts of the mixture rather than unrestrained amounts. These proportions are measured by volume, by weight, or by mole fraction. These are nonnegative numbers, and, if expressed as fractions of the mixture, they must add up to a unity, especially if the ingredients to be studied are the only ingredients comprising the mixture.

So you realize, how the process and the recipe, are important in development process. How do we get about with them? Let's get to know.

14.3.2 Modelling for process and recipe

Generally, all problems that appear in food product design can be divided into mixture or process problems, with the latter having the dominant share. Sometimes a problem that seems to be a mixture problem is really a process problem and can only be solved with a corresponding factorial experimental method. As explained above, the difference between a process and a mixture study is quite distinct, and these studies need different statistical experimental techniques to deal with. In practice, it is not easy to distinguish a process problem with a mixture problem, when the food product design is only concerned with recipe or formulation development. To get a better understanding of the difference between them, a short description of performing a factorial experiment for solving a process problem and of running a mixture experiment is given:

1. *A factorial experiment*: It studies the effect of some independent variables on food quality indices (response) through varying two or more of these independent variables, such as temperature, time, pressure and pH value. A series of values or test levels of each factor is selected, and certain combinations of their levels are tested.
2. *A mixture experiment*: An experiment in which the food quality indices (response) are assumed to depend only on the relative proportions of the ingredient components present in the mixture and not on the amount of the mixture. In such an experiment, if the total amount of the mixture is held constant, the value of the response changes when changes are made in the relative proportions of the ingredients.

The development of bakery powder is described as a practical example that will help you in understanding the difference between a factorial and a mixture experiment.

A premixed bakery powder for biscuit making consists of wheat flour *F* and three different chemical compounds *A, B* and *C*, which would be tested in the biscuit making according to a standard bakery experiment. The flour is used as a diluting medium, whereas A, B and C will be effective at different baking temperatures or baking phases. To develop an optimal baking powder formulation from F, A, B and C, the effect of various formulations are tested. Three different statistical experimental approaches are applied.

Strategy 1

Wheat flour F 3940 g is, mixed with 60g of A, B and C, yielding a ratio of chemicals to flour of 3:197 in all formulations. All mixtures are produced in total amount of 4000 g. In all tests, the amount of flour F in the baking powder is fixed, and the amounts of the three chemicals A, B and C are varied as indicated in Table 13.1.

Table 13.1: Mixture Experiment (Strategy 1)

Chemicals (g)				Flour (g)		Chemicals (%)				Flour (%)	Total	Ratio of Chemical: F
A	**B**	**C**	**Total**	**F**	**Total (g)**	**A**	**B**	**C**	**Total**	**F**	**(%)**	
40	10	10	60	3940	4000	1.00	0.25	0.25	1.5	98.5	100	3:197
30	15	15	60	3940	4000	0.75	0.375	0.375	1.5	98.5	100	3:197
30	20	10	60	3940	4000	0.75	0.50	0.25	1.5	98.5	100	3:197
20	20	20	60	3940	4000	0.50	0.50	0.50	1.5	98.5	100	3:197

Strategy 2

The wheat flour amount is fixed at 3940g, but that of the active ingredients is varied from 30 to 60 g with the ratio of A : B : C fixed at 3:2:1. The combinations to be tested are listed in the table 13.2.

Table 13.2: Mixture Experiment (Strategy 2)

Chemicals (g)				Flour (g)		Chemicals (%)				Flour (%)	Total	Ratio of Chemical: F
A	B	C	Total	F	Total (g)	A	B	C	Total	F	(%)	
30	20	10	60	3940	4000	0.750	0.500	0.250	1.500	98.500	100	0.0152
25	16.7	8.3	50	3940	3990	0.627	0.418	0.209	1.254	98.746	100	0.0127
20	13.3	6.7	40	3940	3980	0.502	0.335	0.167	1.004	98.996	100	0.0101
15	10	5	30	3940	3970	0.378	0.252	0.126	0.756	99.244	100	0.0076

It is a single-factor experiment with four test levels of baking powder. Actually only the ratio of chemicals to flour are changed in the study. In this way the effect of changing the chemicals: flour ratio or of changing the amount of chemicals while holding the amount of flour constant can be measured. In this experimental design the effect of ratio of the chemicals to flour would be examined. Note that if the percentages of A, B and C are varied in addition as in the first experiment, this would then constitute a flour-component, mixture-amount experiment.

Next look at the third strategy.

Strategy 3

Two levels of wheat flour 3960g and 3940g and two levels of baking powder 60g and 40g are selected to be tested. In all trials the percentages of A, B and C are fixed at 3:2:1. The formulations are as in Table 13.3. This is obviously a factorial experiment in which we are interested in measuring how the biscuit quality will be influenced by changing the level of flour and chemicals.

Table 13.3: Mixture Experiment (Strategy 3)

Chemicals (g)				Flour (g)		Chemicals (%)				Flour (%)	Total	Ratio of Chemical: F
A	B	C	Total	F	Total (g)	A	B	C	Total	F	(%)	
30	20	10	60	3940	4020	0.497	0.497	0.249	1.5	98.50	100	0.01523
30	20	10	60	3940	4000	0.500	0.500	0.250	1.5	98.50	100	0.01523
15	10	5	40	3960	4000	0.250	0.250	0.125	1.0	99.00	100	0.01010
15	10	5	40	3940	3980	0.254	0.254	0.127	1.0	99.00	100	0.01010

The example above gives a fair idea about how the factorial, mixture experiments are conducted for product development. With this we end the first section. Read the points to remember given herewith to recapitulated what you have learnt so far. Now attempt the check your progress exercises given herewith to judge for yourself how much you have grasped about the subject so far.

Points to remember

1. Product development is an innovative activity designed to meet the identified needs in the market.
2. Consumer perception and preference have to be studied while formulating a new product.
3. Product development comprises formulation, standardization of processing method and evaluation and testing of final product.
4. The simplest methodology in product development is the trial and error method.
5. Statistical methods of product development are Factorial experiment and mixture experiment.

Check your progress Exercise 1

1. Define product development

   ----

2. List the factors influencing product development.

   ----

3. What is trial and error method?

----

4. What are Independent and dependent variables?

----

5. What are factorial experiment studies?

----

6. What is a mixture experiment?

The next crucial aspect of product development is sensory evaluation i.e. to evaluate the product on the basis of appearance, acceptability on part of the consumer or on information based on food acceptance data. These aspects are discussed within the next sub-section entitled sensory evaluation.

14.4 SENSORY EVALUATION

We begin our discussion on sensory evaluation by first understanding what we mean by sensory evaluation. *Sensory evaluation is a scientific discipline used to evoke, measure, analyse and interpret reactions to those characteristics of foods and material as they are perceived by the senses of sight,smell, taste, touch and hearing.* Next, why use sensory evaluation? Well, sensory evaluation is used to:

- evaluate a range of existing food products
- analyse a test kitchen sample for improvements
- gauge consumer response to a product
- check that the final product meets its original specifications

One may further wonder, why does the food industry need sensory assessment? Well, the food industry always try to :

- develop new products by modifying existing formulations
- enter new markets
- compete more effectively in existing market
- keep a high level of quality

These compulsions, therefore, make sensory evaluation very essential. Food quality, or from the *consumer view point*, food acceptance is the most critical aspect of food. The collection of *food acceptance data* is a key component in studies on product development, quality control, food product acceptance in the market place and food service evaluation. How is this data collected? What are the different processes involved in the assessment of the product being developed? Usually, a sensory panel is constituted to conduct periodic quality assessment of the product, followed by consumer testing. Let's learn about these processes.

A. Sensory panel

During the product development cycle it is necessary to conduct periodic quality assessment of the product being developed. This is done either with a consumer panel or a trained panel. Both kinds of panels are required as constituents of product development team. The trained panel is selected and trained in such a way that the panelists are capable of giving high reliability of judgments independent of psychological factors such as bias, motivation and individual experience. The expert is not viewed as representing the consumer. The role of the expert in product development is to determine flaws in the development process (too salty, poor texture etc), and possibly to attribute these flaws to specific processing steps, eg: burnt note attributable to overheating or higher processing temperature. This information is used by the developer to alter the formulation or to improve processing. As a result of experimentation and sensory evaluation an optimized product is developed. This is then submitted to a consumer to be maximally effective.

B. Consumer testing

Consumer testing is the next crucial aspect in product development. Consumer testing can be done in three ways:

1. in-house laboratory testing
2. home testing and
3. institutional testing

Let us discuss each of these next.

1. In-house laboratory acceptance testing represents the most controlled environment in which to conduct acceptance tests. Within the laboratory testing area, one can control a number of environmental variables (odour, light, temperature, humidity etc) and a number of stimulus variables (serving temperatures, portion size etc). In-house testing utilizes either laboratory personnel or consumers brought in for the tests.

2. In home testing, the selection and maintenance of a consumer panel is a key issue. The co-operation rate from consumer home panels is approximately 50 percent. It has been found that co-operation is best in households with:

a) more than two members
b) a younger housewife and
c) more education.

But home testing presents a practical problem, that is, the process of data collection is not done under the supervision of the investigator. Therefore, validity of the procedure and resulting data cannot be directly assessed.

3. The institutional food service setting, on the other hand, provides an excellent opportunity to collect food acceptance information. It is preferable to collect the food acceptance ratings from the consumers as they are eating, or just after they have completed eating. Collection of direct consumer acceptance ratings also provides the researcher with an opportunity to observe the food system in operation and to interact with consumers. Food acceptance data is collected by using feedback forms that are filled by the consumers. For their effective use the feed back forms should be brief and clear; it

should take only 1–2 min to fill out. Secondly, the format of questions should provide information which can be acted upon. Data collected on a number of food products showed that the card or form with different scales for different food attributes was most effective and useful. One example of a feed back form used in the consumer testing of low fat cake is given here.

FEED BACK FORM

After you have tested the ***Low Fat Cake***, please rate it for each of the following characteristics by checking one box in each category.

Temperature	**Flavour**	**Portion Size**	**Texture**
Too Hot ☐	Good Flavour ☐	Too Big ☐	Bad Texture ☐
Slightly Too Hot ☐	Slightly Good Flavour ☐	Slightly Too Big ☐	Slightly Bad Texture ☐
Just Right ☐	Neutral Flavour ☐	Just Right ☐	Neutral Texture ☐
Slightly Too Cold ☐	Slightly Bad Flavour ☐	Slightly Too Small ☐	Slightly Good Texture ☐
Too Cold ☐	Bad Flavour ☐	Too Small ☐	Good Texture ☐

Considering everything, how was the ***Low fat Cake***
Good ☐ Slightly Good ☐ Neutral ☐ Slightly Bad ☐ Bad ☐

COMMENTS

You would have made note of the fact that food acceptance data is collected by the consumers by using feedback forms. There are a few acceptance tests normally carried out to evaluate product acceptability. What are these tests and how they are conducted? How is the sensory evaluation carried out during the product life cycle? These are some other crucial aspect we should know while on the topic of sensory evaluation. Read the next sub section and find out.

14.4.1 Acceptance tests

What are *Acceptance Tests*? Acceptance tests are used to *evaluate product acceptability or liking or to determine which of a series of products is the most acceptable or the most preferred.* It should, however, be emphasized that acceptability and preference are not the same thing. For example, a person may prefer product A to product B, but actually find them both unacceptable.

Information derived from acceptance testing will only be of value if it reflects the results that would be obtained in the population at large, and this is unlikely to be achieved unless a panel which represents the target population is recruited. Such consumer panels are usually quite large, and their use in product testing has tended to be the responsibility of the market researcher rather than the sensory analyst. However, there are common features in the test methodology and common products being studied, so it is appropriate for the sensory analyst to be aware of the existence and purpose of these acceptability tests, if only in the interests of the effective interdepartmental communication. In addition, the sensory analyst can sometimes apply acceptance tests in a limited way to obtain an indication about product acceptability and may be asked to pilot such "consumer guidance" tests during product development and before products are subjected to more detailed market research.

There are three main methods of sample presentation that are used in acceptance tests – *monadic, sequential monadic and paired presentation*.

1. In *monadic tests*, samples are presented one at a time.
2. In s*equential monadic tests*, samples are presented in sequence, to be assessed one at a time.
3. In *paired tests*, samples are presented two at a time, generally with some form of direct comparison in mind.

What are the Types of Acceptance Tests?

There are two main aspects to acceptance testing:

- Measurement of Acceptability

- Comparison of acceptability or preference

These tests supply information about people's likes and dislikes of a product. Note, these tests do not intend to evaluate specific characteristics, such as crunchiness or smoothness. A discussion on these tests follows:

a. Hedonic Rating

In this test the assessor is asked to record the extent of liking for a product, usually by selecting a category on a "hedonic" or liking scale that runs from "extreme like" to "extreme dislike". A number of different scales have been developed and used.

A very popular scale is the following nine – point hedonic scale:

- Like extremely
- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much
- Dislike extremely

The categories on this scale are equally spaced and it is quite common for the data to be analysed by assigning the values 1 to 9 to the categories on the scale, and then assuming that the intervals are equal. With this assumption, the data can be summarized by recording average liking "Scores".

b. Interval Scales

An alternative approach is to rate liking on a proper interval scale or on a continuous line – scale, with only the ends of the scale being labeled " extreme like" and " Extreme dislike'. The distance of the mark along the scale or line can then be used as a genuine score.

c. Ratio scales

It is also possible to record liking or acceptability using magnitude estimation scaling methods, but consumers may find it difficult to handle the concept of ratios without some initial practice, and may also feel uncomfortable with the arbitrary liking score that must be defined for the opening reference product.

d. Paired Comparison (Preference) Test

In this test the assessor is presented with two coded products and asked to indicate whether there is a preference between them. The test design should ensure that each sample is assessed equally often in first and second position.

The panel size should be at least 50. If the panel is drawn from staff on site, care should be taken to exclude people who may have particular knowledge of the nature of the work or knowledge of the objectives for carrying out the work. Bear in mind that such a panel is unlikely to be representative of the target consumer population.

At the simplest level the assessor is asked to state which sample is preferred and to offer reasons for preference. No – preference discussions are usually allowed and although, they are excluded from analysis, they are usually reported. This is a two – tailed test, as it is not known in advance which product is preferred, and both directions are of equal interest. The basic statistical analysis is by reference to two – tailed binomial tables, and the reasons for preference are tabulated.

Comparative assessments of acceptability or preference can be undertaken using the paired (preference) method or by the ranking test.

What Sort of Panel Is Required for Acceptance Tests?

Consumer panels are the best group to use for evaluating the acceptability of a product or a range of products because they can be recruited to a quota that matches the profile of the target consumer population in terms of product usage, demographics etc. when using consumers for such tests, there are relevant codes of practice and guidelines to be followed.

An *untrained panel* of at least 50 people, possibly drawn from an "in-house" panel of company employees may on occasion be asked to evaluate the acceptability of a product or a range of products. However, this panel will not normally be representative of the target consumers, so should only be used to provide an initial indication of acceptability or as a "consumer guidance" study. As always this panel should be drawn from people who have no particular knowledge of the nature of the work.

Under no circumstances should a *trained panel* be asked to evaluate the acceptability or preference of a product. Training encourages assessors to be diligent in focusing on objective measurement and generating information on the full range of product attributes. They can no longer be expected to behave as naïve consumers and provide simple subjective value judgments.

After a detail discussion of sensory tests and evaluation let us learn about the role of sensory evaluation during the product life cycle.

14.4.2 Sensory evaluation during product life cycle

The basic procedure for developing a new product, and supporting it while marketed, included distinct steps that are constant no matter what type of product is produced.

Initial screening in product development roughly defines the final product. The objective during this phase of life cycle is to formulate and physically prepare a prototype that is close to the final product, yet knowing the product will go through extensive optimization. The different stages during product life cycle are summarized herewith:

A. Product Optimization

Sensory analysis during this phase of product development is critical and includes extensive evaluation with many kinds of tests, each playing a specific role in optimization of the new product. Trained descriptive panels are used to characterize the flavour profile and other characteristics compared to what is already in the market. Consumer panel are used to determine product acceptability and aid in defining the formula and product specifications such as moisture, oil, salt, seasoning and oil flavour in fresh and aged products. Product testing by consumer panel can be conducted by the company developing the product or by an independent consumer evaluation agency.

B. Scale up

At this phase, sensory analysis consists of tests that compare the production samples with the optimized product. Depending on the resources available, either consumer panels or descriptive panels can qualify the production samples.

Sensory specifications are also determined before the product is taken into full production. This is a time consuming-process, similar to establishment of analytical specifications. The first step consists of screening of samples that represent reasonable extremes in the manufacturing process and also represent different raw material samples. Descriptive analysis is then used to characterize the products in quantitative terms. Consumer data are used to determine which attributes are critical and to set acceptable limits around the optimum target.

C. Production

Sensory analysis does not stop after the product has been developed and is being produced routinely. However, it is critical that products continue to be analyzed to ensure the finished goods are consistently manufactured to design criteria and that the product profile does not "drift" over time.

Typically, products and packages are inspected shortly after production in what is sometimes called a sample-cutting meeting. Persons involved in evaluating freshly made products must become familiar with how products with varying characteristics age during their expected shelf life. Traditional difference and / or variation testing should be conducted on a routine basis for quality assurance purposes. At this point, shelf-life testing should be conducted to ensure the product meets specifications till the end of its declared shelf life.

The entire discussion so far has been summed up in points to remember. Read them carefully**.** Next, answer the check your progress exercise to recapitulate what you have learnt so far**.**

Points to remember

1. During product development cycle it is necessary to conduct periodic quality assessment by employing sensory evaluation methods.
2. A trained sensory panel helps in development of the formulation and improving / modifying processing steps.
3. Consumer acceptance data is vital for studying the product quality and to predict acceptance in the market.
4. Hedonic rating is a well known acceptance test. Usually a nine point hedonic scale is used.
5. In paired comparison test the assessor is asked to indicate whether there is a preference between two samples.
6. Sensory evaluation during product life cycle consists of initial screening, product optimization, evaluation of product prepared during scale of studies and during regular production.

Check Your Progress Exercise 2

1. What is a trained sensory panel?

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2. Name the three ways in which consumer testing can be done.

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3. Why are acceptance tests used?

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4. Give the nine point hedonic scale.

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5. What is paired comparison test?

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6. Mention the stages in product life cycle, at which sensory evaluation is used.

So far we have learnt about the need for developing a product and the methodology of doing it. Now let us learn what are the ingredients that could be used in a product too make it a speciality product.

14.5 NEW PRODUCTS AND INGREDIENTS

Present day needs as well as future trends in food product development are taken into consideration in selecting the ingredients.

Increasingly the issue for the food industry becomes one of understanding the health benefits of food and diet and of targeting research towards elucidating the physiologically active components and their mechanisms of action. Many of these physiologically active compounds are found in well-known food sources, in addition to those less recognized. Soya, cereal bran, onion, garlic, many fruits and vegetables, are just a few among a wide variety of foods with potential health benefits. Research designed to understand and enhance these benefits is critically important. Clearly, such a targeted approach could lead to the development of "functional foods". What are these functional foods? The next sub-section focuses on this aspect.

14.5.1 Functional Foods

Traditionally, food products have been developed for taste, appearance and convenience for the consumer. With the increasing awareness of the role of diet in disease prevention there is an emergence of a new category of food products which provide health benefits. Generally, this type of foods, are called as *functional foods*. *These foods provide nutrition as well as certain health benefits*. A functional food is similar in appearance to conventional foods. It is consumed as part of a usual diet and has physiological benefits and / or reduces the risk of chronic disease. Functional food is also known as *" A food that has a component incorporated into it to give a specific medical or physiological benefit, other than a purely nutritional benefit"*. In other words these are the food products having a defined and well established health claim.

Health claim can relate to components of food or foods themselves. Three types of health claim are:

1. generic
2. commodity specific and
3. product specific.

Generic health claims are those that relate a nutrient of a food product to a particular disease or condition. One example of health claim permitted in USA is as follows: *"Diets low in saturated fat and cholesterol and rich in fruits, vegetables and grain products that contain some type of fibre, particularly soluble fibre, may reduce the risk of heart disease, a disease associated with many factors"*. On the basis of this statement, new products containing one or more of the above ingredients could be developed.

Commodity claim describes the claim for commodities or ingredients. Statements permitted in USA for oatmeal and oat bran reads: "*Diets high in oat bran / oatmeal and low in saturated fat and cholesterol may reduce the risk of heart disease"*. This highlights the health benefits of oat bran and meal. However, it does not indicate in the claim that the product on which the claim is placed is protective.

A product specific claim states that the product on which the claim is placed has a protective effect against a disease. For this type of claim, the product itself, rather than the ingredients or nutrients in it, have to be shown to have benefit. In all the above three types of claims, it is essential to provide scientific evidence in support of the beneficial effect of the commodity or ingredient or the product in the prevention or treatment of a condition.

From the above information, we have a fair idea about how to plan development of a functional food. In order to do this, we must know about the special ingredients required for the formulations. A few such ingredients are described here.

A. Oat products

Oats fulfill admirably the description of a functional food, as one that, in addition to providing all normal attributes of a food – basic sustenance, pleasing taste and texture – also confers a specific health benefit.

The outer layers of oats are similar to those of other cereals in being a good source of insoluble dietary fibre with the attendant capacity to improve colonic function and possibly reduce the risk of colon cancer. Many other functionally distinct components such as waxes, lignin, phytate, vitamins, minerals and phenolics concentrate in these layers. Some of these compounds are powerful antioxidants and may possess potent pharmacological properties. The Food and Drug Administration (FDA) of the USA has recently allowed a health claim for an association between consumption of diets high in oatmeal, oat bran, or oat flour and reduced risk of coronary heart disease. This represents the first health claim for a specific food under the Nutrition Labeling and Education Act (1990).The overall conclusion from the FDA review was that oats could indeed lower serum cholesterol levels, specifically low-density lipoprotein (LDL) cholesterol, without change in the high-density lipoprotein (HDL) fraction; on this basis a health claim for reduced heart disease risk was allowed. The FDA has allowed that the main active ingredient, in this respect, is the soluble fibre (1->3) (1->4)-β-D-glucan, or β-glucan.

B. Wheat bran

The useful role of wheat bran in promoting regularity in colonic function and preventing constipation is generally accepted. In addition, growing research has focused its protective effect against colon and breast cancers.

Amount of fibre in the diet has an effect on colonic function, the type of fibre and its digestibility or fermentability also play a significant role. Both soluble and insoluble fibres have value in promoting regularity in colonic function, as measured by stool weight and transit time, but they promote regularity via different mechanisms. Insoluble fibres, such as those from wheat bran, are resistant to fermentation by colonic bacteria and increase fecal bulk by retaining water.

Among the different sources of dietary fibre as fecal bulking agents, wheat bran is probably the most studied and among the most effective. Wheat bran ranked among the highest in fecal bulking, exceeding fibres from fruit and vegetables, gums and mucilages, cellulose, oats, corn, legumes and pectin.

From a food processing perspective, the range of particle size in commercially available wheat bran offers many functional benefits. While fiber particle size may affect its colonic effects, the range of particle size typically found in commercially available wheat bran (coarse bran > 1400 μm to very finely ground bran <500 μm) is well within that reported to be associated with fecal bulking effects.

C. Rice bran

Rice bran contains primarily insoluble fiber (cellulose) and soluble fiber (hemicellulose). Insoluble fiber adds bulk to the gastrointestinal (GI) track in humans causing more frequent stools that pass through the system more quickly, requiring less pressure to expel, and absorbing more bile acids thereby preventing their re-entry into circulation. This lowers the amount of bile absorption/reabsorption of dietary and or endogeneous lipid by the lower intestinal tract and promotes the synthesis of more bile acids from available cholesterol. Lowering serum cholesterol levels in the blood, specifically the low-density lipoprotein (LDL) fraction, aids in cardiovascular health and tends to lessen gallstone formation.

Rice bran is potentially valuable source of natural antioxidants such as tocopherols, tocotrieols, and oryzanols. Increased concern over the safety of synthetic antioxidants like butylated hydroxynisole (BHA) and butylated hydroxytoluene (BHT) has increased the interest in finding effective and economical antioxidants. Antioxidants extracted from rice bran potentially could satisfy this demand.

Defatted rice bran contains an increased percentage of fiber ranging from 35 – 48%, and can be used in speciality high – fiber products and baked goods. Rice bran fractions also possess emulsifying and foaming properties for baked products, meringues and whipped toppings. These fractions reportedly provide other benefits, such as leavening and texturization.

D. Soya bean products

Soya bean and its flours are used in the preparation of a variety of fermented and non-fermented products in Asian countries. However in India, food use of soya bean or soya flour is limited to a few extruded and texturised products. Soya proteins are known to reduce cholesterol levels in hypercholesterolemic individuals. The effect is greatest on those with the highest starting levels of cholesterol. These findings strongly support the inclusion of soya proteins (soya protein isolate and soya protein concentrate) in a wide variety of common food products. An average of 17-25 gms of soya protein per day was found to be effective in lowering serum cholesterol. Epidemiological and animal studies have indicated that there could be a correlation between consumption of soya proteins and certain chronic diseases like breast and prostrate cancer. In India food grade soya meal (defatted soya flour) is available which can be used in formulation of new foods having health benefits.

E. Grapes

The components of grapes and grape products believed to play a significant role in preventing or delaying the onset of diseases including cancer and cardiovascular diseases are the phenolic compounds. These compounds are secondary plant metabolites that contribute in an important manner to the flavour and colour characteristics of grapes, grape juices and wines. The phenolic compounds of grapes include phenolic acids, anthocyanins, flavonols, flavan-3-ols, and tannins. The flavonoids (C6-C3-C6), which include the anthocyanins, flavonols and flavan-3-ols, are powerful antioxidants, and are found in high concentration in grapes and grape products. These compounds exhibit a wide range of biochemical and pharmacological effects including antiinflamatory and antiallergic effects.

From the foregoing, it is evident that the grapes and grape products are rich in phenolic compounds, particularly flavonoids, which have demonstrated a wide range of biochemical and pharmacological effects, including anticarcinogenic, antiatherogenic, anti-inflamatory, antimicrobial, and antioxidant activities. The available information suggests that the regular consumption of currently available grape products should have a long-term health benefit. However, for increased concentration of grape phenolics, such as resveratrol, ellagic acid and flavonoids, new food products rich in these phytochemicals need to be developed. The byproducts of wine-making, grape skins, seeds and cluster stems are rich in catechins, proanthocyanidins and/or natural antioxidants, which can then be incorporated in the variety of foods such as breakfast cereals, bakery products and confectionaries.

F. Citrus Fruits

A large number of constituents in citrus products have been shown to be capable of preventing or alleviating diseases and promoting health. Vitamin C, E, and carotenoids, for instance, are thought to play a role in preventing or delaying the onset of major degenerative diseases of aging such as cancer, cardiovascular disease, and cataracts by counteracting oxidative processes. Similarly, several “non nutrient” components of citrus, including limonoids and flavonoids, appear to inhibit carcinogenesias by acting as blocking and / or suppressing agents.

G. Onion and Garlic

Onions (*A. cepa*), and garlic (*A. sativam*), have been used in traditional and folk medicine for over 4000 years. Disorders for which both garlic and onions have been used include asthma, arthritis, arteriosclerosis, chicken pox, the common cold, diabetes, malaria, tumors and heart problems. Modern science has shown that alliums and their constituents have several therapeutic effects, including *antiplatelet aggregation* activity, *fibriolytic activity,* anticarcinogenic effects, antimicrobial activity, and anti-inflamatory and anti-asthmatic effects.

Onion and garlic based products are currently marketed in a variety of forms. They include, for onions: dehydrated onion pieces, onion powder, onion flavourings, encapsulated flavours, oleoresins and essential oils, onion salt, pickled onions, canned, frozen and packaged onions; for garlic: dehydrated garlic powder, garlic salt, garlic juice, and garlic flavouring, encapsulated flavours, oleoresins and essential oils.

The processed products have considerable advantages to the food industry. The reduction in bulk means lower transport and distribution costs, the products are not subject to seasonal fluctuation in availability and prices, are more reproducible in organoleptic quality, and are more readily dispersed in food products than is the case with the chopped, sliced or blended fresh or stored vegetables.

The primary function of existing onion and garlic products is to provide consumers with the characteristic pungent flavour imparted by volatile sulfur compounds. In the past, value of both garlic and onion in disease prevention and health promotion, has been of little consideration in the development of consumer products from alliums. In recent years, their therapeutic properties have been recognized in the processing of onion and garlic capsules, tablets and even in the development of odorless products. These products, however, are more like drugs than true functional foods. Significant progress has been made in designing lower salt-, lower calorie-, lower cholesterol-, and higher fibre- and calcium containing foods, using new food ingredients, such as artificial sweeteners and carbohydrate or protein-based fat substitutes and new processing methods. Thus, one possible approach in development of novel-value-added allium-based functional foods involves incorporation of garlic and/or onion into food products such as bakery products, imitation meats and sausages, and meat pies. The key to the more widespread and increased consumption of onion and garlic and consequently to the increased exploitation of their medicinal and physiological properties, is improvement or elimination of the flavour of these vegetables.

G. Mustard

Although the primary use of mustard seeds is a condiments, important new food applications are regularly being found. Commercially available mustard products include mustard oil, mustard flour, ground and prepared mustards, and mustard bran. Mustard mucilage has *rheological* and *interfactial* properties that should find a wide range of applications in the food industries. Many of the components of mustard have beneficial physiological effects. These include isothiocyanates for possible effects on cancer prevention and antimicrobial activity; the viscous fibre and its effects on glucose and lipid metabolism; and the potential health benefits of phytates, dithiolthiones and proteins.

H. Marine lipids

Marine lipids originate from the liver of lean white fish such as cod, the body of oily fish such as mackerel, and the blubber of marine mammals such as seal. These oils consists of saturated, monounsaturated and polyunsaturated fatty acids (PUFA). There are two classes of PUFA, namely, the omega-3 and omega-6 families, which are differentiated from one another based on the location of the double bond from the terminal methyl group of the fatty acid molecule. Unlike saturated and monosaturated fatty acids, which can be synthesised by all mammals, including humans, the PUFA cannot be easily synthesized in the body and it must be provided through the diet. The omega-3 family of PUFA is descended from linolenic acid while its omega-6 counterparts are descended from linoleic acid. The unique feature that differentiates lipids of marine species from those of land animals is the presence of long-chain PUFA, namely, eicosapentaenoic acid (EPA; C20:5 ω3), docosahexaenoic acid (DHA; C22:6 ω3) and, to a lesser extent, docosapentaenoic acid (DPA; C22:5 ω3).

Consumption of marine oil results in a decrease in plasma lipids by reduced synthesis of fatty acids and low-density lipoproteins. It has also been suggested that marine oils may retard atherogenesis through their effect on platelet function, platelet-endothelial interactions and inflammatory response.

I. Sources of antioxidants

The primary biological role of antioxidant is in preventing the damage that reactive free radical can cause to cells and cellular compounds. In fact, almost all the food constituents having a protective effect against specific diseases seem to have some kind of antioxidant property. *Free radical is a group of atoms that behave like a unit,* eg.: Carbonate radical, (CO_3^{--}), Nitrate radical (NO_3^-), and Methyl radical (CH_3^-). *Free radical contains one or more unpaired electrons.* Human body naturally produces free radicals as it metabolises oxygen. Reactive free radicals are able to produce metabolic disturbances and to damage membrane structures in a variety of ways. This may lead to cardiovascular disease, cancer and other health problems.

The current dietary recommendation to increase fruit and vegetable consumption is one which is widely perceived as health-promoting. Consistent epidemiological links worldwide between high fruit and high vegetable consumption and a greater life expectancy warrant more emphasis given to this particular dietary recommendation. Fruit and vegetables are the rich sources of the antioxidants, vitamin C, vitamin E, various carotenoids, flavonoids, isoflavones, organo-sulphur compounds, copper, manganese and magnesium and may also contribute to pools of endogenously produced antioxidants such as ubiquinol. Fruit and vegetables, however, are not the only dietary source of antioxidants and other rich sources of vitamin E include nuts and seeds, wholegrain breakfast cereals, wholemeal bread, eggs, margarine, vegetable oils, and dairy products.

A list of plant-based sources of antioxidants is presented herewith.

Plant-based Sources of Antioxidants

I. *Vitamin C (ascorbic acid)* – blackcurrants, green peppers, guava, gourds, greens, strawberries, kiwi fruits, citrus fruits, paw – paws, brussel sprouts, new potatoes

II. *Vitamin E* – sweet potatoes, spinach, broccoli, pulses, kale, tomatoes, asparagus, herbs

III. *Carotenes* – carrots, sweet potatoes, herbs, pumpkins, spinach, greens, kale, canloupes, chicory, squashes, red peppers, mangoes, apricots

IV. *Lycopene* – guaves, pink grapefruits, tomatoes

V. *Lutein and zeaxanthin* – kale, spinack, herbs, greens, celery, scallions, leeks

VI. *Flavonoids* – onions, strawberries, apples, citrus fruits, greens, broad beans, peanuts, grapes, tea

VII. *Isoflavones* – pulses, especially soya bean and linseed products.

VIII. *Organo-sulphur compounds* – allium vegetables; garlic, onions, chives, leeks

IX. *Ubiquinol* – beans, garlic, spinach

X. *Copper* – pulses, mushrooms, olives, gourds, avocados, lychees, blackberries, blackcurrants, kiwi fruits, grapes, mangoes, guaves, bananas, raspberries, plums, asparagus, potatoes

XI. *Manganese* – beetroot, blackberries, pineapples, pulses, spinach, greens, bananas, raspberries

Points to remember

1. Functional foods provide specified medical or physiological benefits.
2. Oats lower serum cholesterol level, specifically LDL cholesterol. Both soluble and insoluble fibres of wheat bran promote regularity in colonic function.
3. Rice bran ids a valuable source of natural antioxidants such as tocopherols, tocotrienols, and oryzanols.
4. Soya protein has the effect of reducing cholesterol levels.

5. Phenolic compounds of grapes play a significant role in preventing or delaying the onset of cancer and cardiovascular diseases.
6. Consumption of marine oil results in a decrease in plasma lipids.
7. Antioxidants prevent the damage that reactive free radicals can cause to cells and cellular compounds.
8. Several fruits and vegetables are rich sources of natural antioxidants.

Check your progress Exercise 3

1. Define functional food.

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2. Name the main active ingredient in oat products.

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3. Mention the role of insoluble fibres from wheat bran.

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4. Name the phenolic compounds of grapes and their significance.

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5. Name the types of food in which onion or garlic can be used for imparting health benefit.

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6. Consumption of marine oils results in:

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7. Name the health benefit of soya protein

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h) Name the plant based sources of the following antioxidants: Vitamin C, lycopene, isoflavones and organo sulphur compounds.

Our last discussion in this unit is on shelf life of products.

14.6 SHELF LIFE

Foods are perishable by nature. Numerous changes take place in foods during processing and storage. It is well known that conditions used to process and store foods may adversely influence the quality attributes in foods. Upto storage for a certain period, one or more quality attributes of a food may reach an undesirable state. At that instant, the food is considered unsuitable for consumption and it is said to have reached the end of its shelf life.

Shelf life of a food product may be actually defined *as the time between the production and packaging of the product and the point at which it becomes unacceptable under defined environmental conditions.* Storage and distribution are necessary links in the food chain, and hence considered as factors influencing the shelf life. We are all aware of the fact that food deteriorates with time and become unacceptable. In this context, it is useful to understand the factors that influence food deterioration. We will learn about these factors next.

14.6.1 Major modes of food deterioration

During storage and distribution, foods are exposed to a wide range of environmental conditions. Environmental factors such as temperature, humidity, oxygen and light can trigger several reaction mechanisms that may lead to food degradation. As a consequence of these mechanisms, food may be altered to such an extent that they are either rejected by the consumer, or they may become harmful to the person consuming them. Chemical, physical and microbiological changes are the leading causes of the food deterioration. A discussion on these changes follows.

Physical Changes

Physical changes are caused by mishandling of foods during harvesting, processing and distribution; these changes lead to reduced shelf life of foods.

Crushing of dried snack during distribution seriously affects their quality.

Dried foods when kept in high humidity may pickup moisture and become soggy.

Chemical Changes

During the processing and storage of foods, several chemical changes occur that involve the internal food components and the external environmental factors. These changes may cause food deterioration and reduce the shelf life. The most important chemical changes are associated with enzymic action, oxidative reactions, particularly lipid oxidation that alters the flavor of many lipid containing foods, and non-enzymic browning that causes changes in appearance.

Fruits upon cutting tend to brown rapidly at room temperature due to the reaction of phenolase with the cell constituents that are released upon cutting of the tissue in presence of oxygen. Enzymes such as lipoxygenase, if not denatured during the blanching process, can influence food quality even at sub-freezing temperatures. In addition to the temperature, other environmental factors such as oxygen, water and pH induce deleterious changes in foods that are catalyzed by enzymes.

The presence of oil and fats containing unsaturated fatty acids is a prime reason for the development of rancidity in foods during storage as long as oxygen is available. Development of off-flavours which is markedly noticeable in rancid foods is the result of autoxidation of unsaturated fatty acids. The generation of free radicals during the autocatalytic process leads to other undesirable reactions, for example, loss of vitamins, alteration of colour, and degradation of proteins. In addition to lipid oxidation, there are other chemical reactions that are induced by light such as loss of vitamins, and browning of meats.

Non-enzymic browning is a major cause of quality change and degradation of nutritional content in many foods. This type of browning reaction occurs due to the interaction between reducing sugars and amino acids. These reactions result in the loss of protein solubility, darkening of lightly coloured dry products and the development of bitter flavours. Environmental factors such as temperature, water activity and pH have an influence on non-enzymic browning.

Microbiological changes

Microbes have the ability to multiply at high rates when favourable conditions are present. Prior to harvest, fruits and vegetables have generally good defense mechanisms against microbial attacks, however, after separation from the plant they can easily succumb to microbial proliferation. Similarly, meat upon slaughter is unable to resist rapidly growing microbes.

Microbial growth in foods results in food spoilage with the development of undesirable sensory characteristics and in certain cases the food may become unsafe for consumption. The pathogenicity of certain microorganisms is a major safety concern in processing and handling of foods upon ingestion. Microorganisms such as *Salmonella* species and *Escherichia coli* strains cause infection while others such as *Aspergillus flavus, Clostridium botulinum* and *Staphylococcus aureus* produce chemicals in foods that are toxic to humans.

From our discussion above it is imperative that we develop mechanisms to determine, monitor and evaluate the shelf life of food products. How is this task done? Let's find out.

14.6.2 Evaluation of food quality

A common practice employed to evaluate the shelf life of a given food product is to determine changes in selected quality characteristics over a period of time. One may consider quality of a food as a gross measure of the food deterioration occurring in food item. However, it should be recognized that the term quality is meant to encompass several quality attributes or characteristics. From a consumer's standpoint, the sensory expectations derived from the presence (or absence) of desirable (or undesirable) characteristics of a given food determine the quality of a product. Therefore a food product noted for its high quality has more of the desirable characteristics.

Empirical or analytical techniques may be used to quantify the quality attributes of food. For example, enumeration of microbes or determination of chemical components of a product are analytical techniques, whereas the human subjects to monitor changes in the magnitudes of quality characteristics constitute empirical techniques.

14.6.3 Procedures for determination and monitoring of shelf life

Direct shelf life determination requires batches of samples to be taken at significant stages in the development or modification of the product. These samples should be examined during storage, usually under controlled environmental conditions, until their quality becomes unacceptable. *The time when this occurs is the maximum product shelf life*, and therefore the determination necessarily requires at least this time to complete.

Significant sampling stages within the programme of shelf life evaluation include:

1. The successful experimental kitchen or pilot plant batch. At this stage it is possible to investigate formulation, process or packaging changes to improve the shelf life without the costs of factory time and material quantities.
2. The successful full scale factory batch. This is the most important sampling stage. This will provide the data for the setting of shelf life and specification standards.
3. The first continuous production trial. Examination of products should confirm the data from earlier samplings.

As part of an on-going surveillance system, samples should be taken at suitable intervals for storage trial. The sampling interval should typically be 20% of the shelf life which will provide samples of 6 different ages from fresh to full shelf life. For long life products more frequent intervals may be useful to detect any changes in storage performance (e. g. every two months for a two year shelf life).

Shelf life samples should be subjected to conditions effectively simulating the normal storage and distribution conditions the food is likely to encounter.Shelf life examination is done by employing appropriate methods of: sensory evaluation; chemical analysis and microbiological analysis.

In sensory evaluation appearance, smell, texture and flavour being the main attributes to assess. Such assessments are frequently inexact as there may not be a suitable control sample with which to compare the stored samples, this being particularly so for new products. However, under appropriate test conditions using control sample it is possible to get a fair idea about the quality and acceptability of stored products.

Quantitative measurements, for example of colour, texture, viscosity and amount of water or oil separation should be included if they either closely relate to the sensory quality or can be used as reliable indicators of quality deterioration.

In addition to subjective assessments, other tests may be necessary. These may include tin content of products in unlacquered cans, vitamin content where a claim is made. Microbiological examination of fresh and stored products is highly essential in order to determine whether they are safe for human consumption.

Points to remember

1. Shelf life of a product is the time between the production and the point at which it becomes unacceptable.
2. Mode of distribution and environmental conditions of storage also influence the a shelf life of a product.
3. Chemical, physical and microbiological changes are the leading causes of food deterioration during storage.
4. Shelf life examination is done by employing methods of sensory evaluation, chemical analysis and microbiological analysis.

Check your progress Exercise 4

1. Define shelf life.

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2. List the major chemical changes occurring in food.

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3. Name the harmful microorganisms found in food.

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4. Mention the sampling stages of shelf life evaluation.

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5. Methods of shelf life examination are:

14.7 LET US SUM UP

In this unit, we studied about product development, which is an innovative activity designed to meet the demands of the market. There are various factors influencing the product development activity. As you learnt, the process of developing a new product comprises of formulation or recipe development, standardization of processing methods and evaluation and testing of quality parameters of the final product. While studying this process, you got to know that the simplest method in product development is known as one factor at a time, or trial and error method.

You also studied about the various problems that appear in food product design. These can be divided into two types- mixture problem and process problem. Further, we learnt that functional foods have physiological benefits and reduce the risk of chronic diseases. Some of the food ingredients of this category are oat products, wheat bran, rice bran, soya products, fruits onion and garlic, mustard and marine lipids. The types of health claims are: generic, commodity and product specific.

Finally, we learnt that shelf life of a food product is a crucial time. Other factors that affect the shelf life are mode of distribution and environmental conditions.

14.8 GLOSSARY

Acceptance test **:** a method of evaluating product acceptability or liking by adopting a suitable sensory evaluation procedure.

Factorial experiment **:** a design of experiment to study the effect of independent variables on food quality indices.

Hedonic rating **:** a sensory evaluation method using a nine point scale that runs from like extremely -------neither like nor dislike ------dislike extremely.

Mixture experiment **:** an experiment in which food quality indices are assumed to depend on ingredient components.

Shelf life **:** time between the production and packaging of the product and the point at which it becomes unacceptable under defined environmental conditions.

Statistical experimental method **:** product development activity carried out according to the statistically designed experimental method.

14.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Product development is a future oriented practice and an effort to foresee the future needs of the market place and to translate this information into new products.

2. The factors influencing product development are: growing urbanization, changes in life style, increasing number of small families and working women and the rise in power of purchasing consumers.

3. Trial and error method is the simplest methodology in product development. Only one ingredient in the formulation is changed at a time and its effect on the quality of the final product is tested.

4. Independent variables are the parameters such as ingredients and processing condition which have effect on product quality. Dependent variables also known as responses are the important measurable food quality indices.

5. Factorial experiment studies determine the effect of some independent variables on food quality indices through varying two or more independent variables.

6. Mixture experiment is an experiment in which food quality indices are assured to depend on the relative proportion of ingredients.

Check Your Progress Exercise 2

1. A sensory panel is the panel of members of which are capable of giving high reliability of judgements, independent of psychological factors such as bias, motivation and individual experience.

2. The three ways by which consumer testing can be done are: inhouse laboratory testing, home testing and institutional testing

3. Acceptance tests are used to evaluate product acceptability or liking or to determine which product is the most acceptable or the most preferred.

4. The nine point Hedonic scale is: Like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely.

5. In paired comparison test, the assessor is presented with two products and asked to indicate whether there is a preference between them.

6. Initial screening, product optimization, scale up and production are the stages in product life cycle at which the sensory evaluation is used.

Check Your Progress Exercise 3

1. Functional food is a food that has a component incorporated into it to give a specific medical or physiological benefit, other than a purely nutritional benefit".

2. Soluble fibre and β-glucan are the main active ingredients in oat products.

3. The insoluble fibres from the wheat bran are resistant to fermentation by colonic bacteria and increase fecal bulk by retaining water.

4. Phenolic acid, anthocyanins, flavonols, flavon-3-ols and tannins are the phenolic compounds of grapes. They prevent or delay the onset of diseases including cancer and cardiovascular diseases.

5. Bakery products, imitation meats and sausages and meat pies are the types of foods in which onion or garlic can be used for imparting health benefit.

6. Consumption of marine oils result in decrease in plasma lipids by reduced synthesis of fatty acids and low density lipoproteins.

7. Soya protein reduces cholesterol levels in hypercholesterolemic individuals.

8. Vitamin C: Greens and citrus fruits
   Lycopene: Guava and tomato
   Isoflavones: Soya bean and linseed
   Organo sulphur compounds: Onion and garlic

Check Your Progress Exercise 4

1. Shelf life is the time between the production and packaging of the product and the point at which it becomes unacceptable under defined environmental conditions.

2. The major chemical changes occurring in food are: lipid oxidation leading to rancidity, loss of vitamins and degradation of proteins; non-enzymic browning resulting in darkening of lightly coloured products; and development of bitter flavour and loss of protein solubility.

3. The harmful microorganisms found in food are *Salmonella* species, *E. coli*, *A. flavus*, *C. botulimum* and *S. aureus*

4. The sampling stages of shelf life evaluation are: Experimental kitchen or pilot plant batch, full scale factory batch and first continuous production trial.

5. Methods of shelf life examination are sensory evaluation, chemical analysis and microbiological analysis.