
UNIT 3 FOOD CONSTITUENTS – CARBOHYDRATES AND LIPIDS

Structure

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3.0 OBJECTIVES

The aim of this unit is to introduce you to the chemistry of two major constituents of foods viz. carbohydrates and lipids. After reading this unit you will become familiar with the following aspects:

- *carbohydrates*: Monosaccharides, disaccharides, oligosaccharides and polysaccharides; their occurrence in foods, structure, properties and uses in food industry; and
- *lipids*: Occurrence, chemical properties, fatty acids and their properties and their changes during processing and storage of foods.

3.1 INTRODUCTION

Carbohydrates along with lipids are the primary source of energy for the human system. Carbohydrates are widely distributed in plants and to a limited extent in animals. They undergo various changes during processing of foods. Lipids are present both in plant and animal foods. They also undergo physical and chemical changes during processing and storage of foods. Therefore, an understanding of the chemical nature of these substances is very important for preserving foods. In this unit you will be learning the chemical aspects of carbohydrates and lipids.

3.2 CARBOHYDRATES

The first products of photosynthesis in plants are carbohydrates. These compounds, in one form or another, constitute more than one half of the organic matter on earth. The major part of plants is built of carbohydrates while the animal world contains rather limited amounts of them.

3.2.1 Occurrence

Carbohydrates occur in plant and animal tissues as well as in microorganisms in different forms and quantities. They along with oils and fats are the primary source of energy for the human system. In plants, a wide variety of monosaccharides and oligosaccharides occur. Starch is the main storage carbohydrate in root crops and cereals. Similarly, the ‘building bricks’ or structural carbohydrates of plants are cellulose, hemicellulose and pectin. Some plants, as well as seaweeds and microorganisms produce different types of gums, which are a different group of polysaccharides. Fruits contain predominantly the monosaccharides, glucose and fructose, and the disaccharide sucrose as well as other mono and oligosaccharides in smaller concentrations. Animal foods have mainly glucose and the storage carbohydrate is glycogen. In milk it is almost exclusively the disaccharide lactose. Another group of polysaccharides called dietary fibre (pectin, hemicelluloses, pentosans, etc.) are gaining considerable health importance. Table 3.1 gives an idea of different types of carbohydrates present in different types of foods.

Table 3.1: Average carbohydrate composition and Water content of some foods

| Carbohydrate | Cereals | | Legumes | | Fruits | | Vegetables | |
|------------------|-----------|----------|-----------|-----------|-----------|------------|------------|------------|
| | Wheat (%) | Rice (%) | Beans (%) | G.nut (%) | Apple (%) | Orange (%) | Potato (%) | Tomato (%) |
| Monosaccharides | | | | | | | | |
| D-Fructose | 0.1 | - | - | - | 5.0 | 1.5 | 0.1 | 1.6 |
| D-Glucose | 0.1 | - | - | - | 2.0 | 2.5 | 0.1 | 1.2 |
| Oligosaccharides | | | | | | | | |
| Sucrose | 1.0 | - | 3.0 | 4-5 | 3.0 | 4.6 | - | 1.0 |
| Polysaccharides | | | | | | | | |
| Starch | 71.0 | 79.0 | 10.0 | 15.0 | - | - | 20.0 | - |
| Pectin | - | - | - | - | 0.6 | 1.3 | - | 0.3 |
| Water | 14.0 | 13.0 | 11.0 | 2.0 | 84.0 | 86.0 | 79.0 | 93.0 |

3.2.2 Nomenclature

Carbohydrates were first named according to their natural sources eg. cane sugar, beet sugar, malt sugar, grape sugar etc. Subsequently they got trivial names often from a prefix related to the source followed by the suffix ‘-ose’. Examples are: fructose (fruit sugar), maltose (malt sugar), lactose (milk sugar), xylose (wood sugar) etc. Though these names do not provide any information on their chemical structure they are still being used widely.

3.2.3 Classification

Carbohydrates are classified into monosaccharides, oligosaccharides and polysaccharides.

Monosaccharides

The simple carbohydrates, the monosaccharides, are neutral, crystallisable substances, which are readily soluble in water. Most of them are sweet covering a wide range of sweetness. Monosaccharides may be divided

chemically into polyhydroxy aldehydes (aldoses) and poly hydroxy ketones (ketoses). Depending on the number of constituent formaldehydes (CH₂O), these sugars are classified as:

| | |
|---|---|
| Bioses (CH ₂ O) ₂ ; | C ₂ H ₄ O ₂ (example: glycol aldehyde) |
| Trioses(CH ₂ O) ₃ ; | C ₃ H ₆ O ₃ (example: glyceraldehyde) |
| Tetroses (CH ₂ O) ₄ ; | C ₄ H ₈ O ₄ (examples: Erythrose, threose) |
| Pentoses (CH ₂ O) ₅ ; | C ₅ H ₁₀ O ₅ (examples: Ribose, rafinose,) |
| Hexoses (CH ₂ O) ₆ ; | C ₆ H ₁₂ O ₆ (examples: glucose, mannose, gulose, galactose, fructose, sorbose) |

The monosaccharides, which are of primary importance in foods, are hexoses and pentoses.

Hexoses: Five hexoses, three of them aldoses (glucose, mannose and galactose) and two ketoses (fructose and sorbose) are found in the free state in plants. The simple open chain formula of these hexoses (propounded by Fisher) are shown in Figure 3.1.

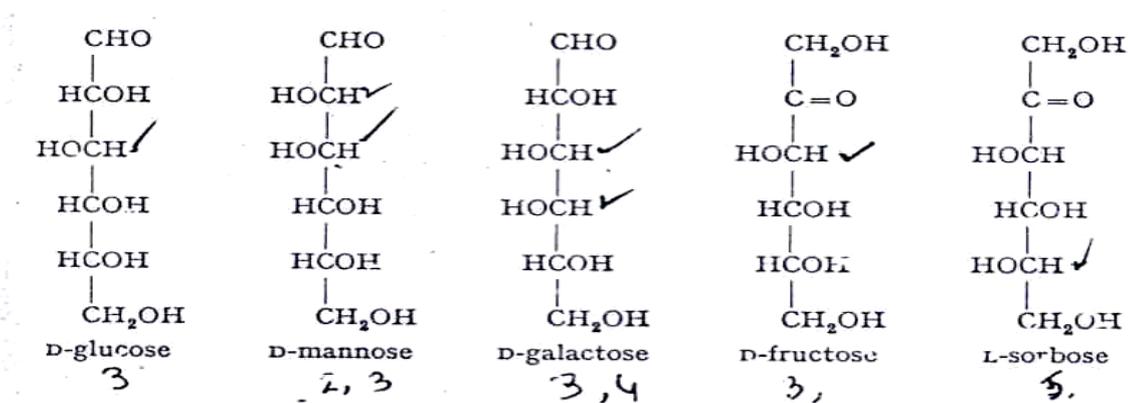


Figure 3.1: Open chain formulae of some hexoses

You will notice that the differences in the structures of these hexoses are in the orientation of the hydroxyl (-OH) groups. Mannose is different from glucose in its configuration at carbon atom 2. Sorbose differs from fructose in its configuration at carbon atom 5. The above formulae of glucose and other sugars show the free carbonyl group and four optically active (asymmetric) secondary hydroxyls. This results in stereoisomerism in sugars. Sugars are designated as D or L. The designation of D or L refers to the two series of sugars, in the D series, the highest number asymmetric carbon has the OH group directed to the right and in the L series this hydroxyl points to the left. The following structures (Figure 3.2) of the simplest sugars, D and L glyceraldehydes explains the series.

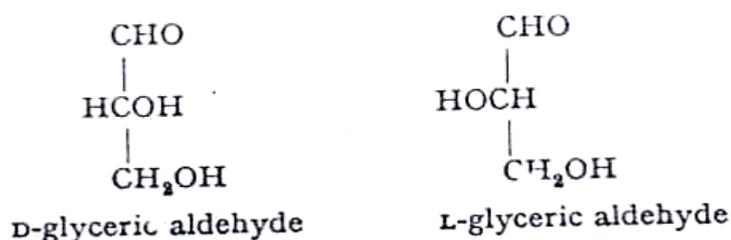


Figure 3.2: D and L glyceraldehydes

Most natural sugars are members of the D series. The open chain formulae of sugars do not explain all the chemical properties. Therefore, various ring structures have been introduced. For example glucose has been assigned a pyranose (6 membered ring) structure and fructose a furanose (5 membered ring) structure.

The simple sugars exhibit a property called optical rotation. You will be learning more on this aspect under polarimetry. In simple terms, optical rotation refers to the property of a substance in solution to rotate plain polarised light to right (dextro rotatory designated by (+)) or to the left (levo rotatory designated by (-)) for example glucose is dextro rotatory and fructose is levo rotatory. A sugar, for example glucose when dissolved in water exist in tautomeric equilibrium between two anomeric forms, each having different degree of optical rotatory power. They are designated as α and β as indicated below (Figure 3.3).

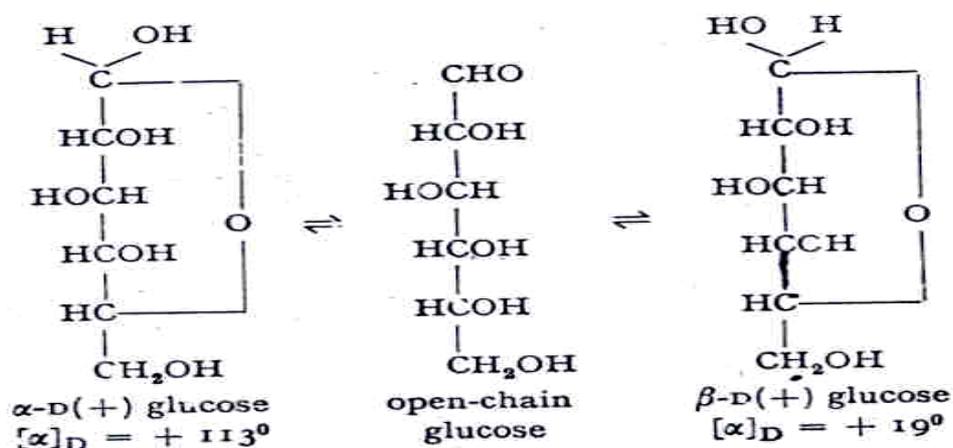


Figure 3.3: α -D and β -D glucose structures

Sugar related compounds present in nature

Amino sugars: Amino sugars usually contain D-glucosamine (2-deoxy-2-amino glucose). They occur as components of high molecular weight compounds such as the chitins of crustaceans and molluscs as well as in certain mushrooms and combined with the ovomucin of egg white.

Glycosides: Glycosides are sugars combined with an alkyl or aryl group. Glycosides are hydrolysed by acid or enzyme to the corresponding sugar and aglicone. Amygdalin is an example of a cyanogenic glycoside, which is present in bitter almonds. Complete hydrolysis of amygdalin yields glucose, benzaldehyde and hydrocyanic acid. Other important glycosides are flavonone glycosides like the citrus bitter principles hesperidin and naringin. Deoxy sugars occur as components of nucleotides like 2-deoxy ribose, which constitute part of deoxy ribo nucleic acid (DNA).

Sugar alcohols: Sugar alcohols occur in some fruits and are produced industrially by reduction of sugars. Reduction of glucose yields sorbitol. Xylitol is a five carbon sugar alcohol. These sugar alcohols are sweet as sugar but are only slowly absorbed in the body and hence are used in diabetic foods. The structure of sorbitol and xylitol are given below (Figure 3.4).

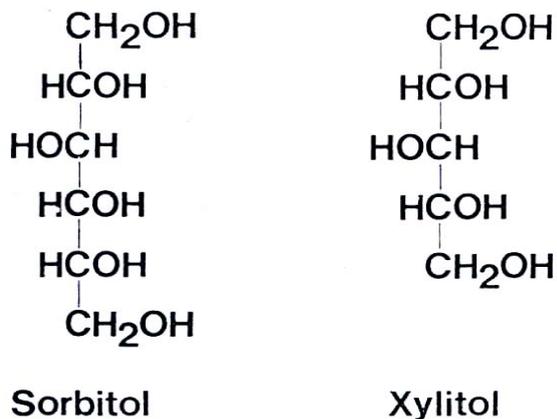


Figure 3.4: Sorbitol and Xylitol

Oligosaccharides

Oligosaccharides are water-soluble polymers of a few condensed monosaccharides. Those most commonly found in foods are homopolymers of D-glucose (e.g. maltose) or heteropolymers of D-glucose condensed with D-fructose (e.g. Sucrose) or D-glucose with D-galactose (e.g. lactose). The above oligosaccharides are di-saccharides. Raffinose a trisaccharide is found in sugar beet. It is a polymer of D-glucose, D-fructose and D-galactose.

Sugars and sweeteners: Sucrose is the most widely used natural sweetener. Of all the sugars, D-fructose is known to be the sweetest. It is customary to compare the degree of sweetness of different sweeteners to sucrose to which the number 100 has been assigned. Fructose has sweetness value of 173.3 and glucose 74.3. Therefore, the hydrolysis product of sucrose (invert sugar containing glucose and fructose) has sweetness value of $173.3+74.3/2 = 123.8$. The relative sweetness of various sweeteners is given in Table 3.2.

Table 3.2: Degree of sweetness of various sweeteners

| Sweetener | Degree of Sweetness |
|------------|---------------------|
| Sucrose | 100 |
| Fructose | 173.3 |
| Glucose | 74.3 |
| Corn Syrup | 30.0 |
| Honey | 97.0 |
| Saccharin | 30,000 – 50,000 |
| Dulcin | 20,000 |

Corn sweeteners: Cornstarch can be hydrolysed by acid or acid-enzyme process to yield smaller and smaller fragments and ultimately glucose (dextrose). The degree of depolymerisation is expressed as dextrose equivalent (D.E.) which is defined as the amount of total reducing sugars expressed as dextrose and calculated as a percentage of the total dry matter.

Glucose syrup is a concentrated solution of sugars obtained by hydrolysis of starch and having D.E. of 20 or more. When a product has a D.E. of less than 20, it is called maltodextrins. Glucose can be isomerised to fructose by an enzyme called isomerase. As fructose is sweeter than glucose, High Fructose

Syrup (HFS) which is sweeter than glucose syrup is prepared using the enzyme.



Check Your Progress Exercise 1

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

1. Define monosaccharides, oligosaccharides and polysaccharides.

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2. Give three examples of hexoses.

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3. Explain optical rotation.

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4. Give two examples of glycosides.

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5. Give two examples of disaccharides.

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6. What is invert sugar? Why invert sugar is sweeter than sucrose?

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Polysaccharides

Polysaccharides are polymers of the simple mannoses, hexoses or pentoses, which occur in nature in different forms. Unlike the sugars they are not sweet

and are mostly insoluble in water. Examples of polysaccharides found in nature are cellulose, starch, pectin and chitin.

Cellulose: The structural materials of the entire plant world consist largely of cellulose. Cotton is essentially pure cellulose. On hydrolysis cellulose yields glucose meaning that it is a polymer of glucose. Celluloses from different sources have molecular weight ranging from 100,000 to 2,000,000.

Cellulose is insoluble in water and most solvents and is relatively resistant to hydrolysis by dilute acids. Man and carnivorous animals are unable to digest cellulose, since they lack the necessary enzymes for its breakdown in their intestines. However, many microorganisms and protozoa are able to break it down. Ruminants are able to digest cellulose because of the presence of these microorganisms in their intestines. Though cellulose has only indirect food value (cellulose feed is converted to meat by animals) it has many other uses like in the manufacture of paper, textiles, explosives, paint, etc.

Starches: Starch is the most important polysaccharide and is distributed widely in nature as a reserve material in plants. It contributes more calories to the normal human diet than any other single nutrient.

Starch from different sources consists of granules of different shapes and sizes. Generally all starches contain two types of molecular structures namely amylose and amylopectin.

Amylose is a long straight chain of glucose units, which reacts with iodine to give blue colour. Amylopectin is a branched molecule consisting of a number of amyloses, which reacts with iodine to give reddish brown colour.

Amylose and amylopectin content of starches from different sources vary. In the most common starches such as corn, rice and potato, amylose is the minor component and represents about 17 to 30% of the total. Some varieties of pea and corn starch may have as much as 75% of amylose.

Starch granules naturally present in plants are completely insoluble in cold water and upon heating they will start to swell and the gelatinisation temperature. Continuation of heating above this temperature results in further swelling of the granule and the mixture becomes viscous and translucent. When such a paste is agitated, the swollen starch granule structure breaks down and the viscosity greatly reduces. When a cooked starch paste is cooled, it may form a gel or under conditions of slow cooling, the linear compound may form a precipitate. This phenomenon called retrogradation. The staling of bread is ascribed to retrogradation of starch. The rate of staling is temperature dependent. Retrogradation is faster at low temperature and hence bread stales more quickly in the refrigerator than at room temperature. Freezing, however, prevents staling and retrogradation of starch.

The functional properties of starches such as its cooked paste viscosity play an important role in their food applications. Cereal starches (corn, wheat, rice and sorghum) form viscous short bodied pastes which set to opaque gels on cooling. Root and tuber starches (potato, cassava or tapioca) form highly viscous paste, which are clear but on cooling become weak gels. Waxy starches (waxy corn and rice) form heavy bodied springy pastes. These pastes

Food Constituents

are clear and have a low tendency for gel formation. High amylose starch requires high temperature for gelatinisation and gives short bodied paste which form very firm opaque gels on cooling. These are suitable for film formation, which find application in coating of fruits as edible coats. In order to impart the desired functioning properties, starches can be modified by certain chemical or enzymes treatments. Such starches are called 'modified starches'.

Pectic substances: Pectic substances occur as constituents of cell walls. In the native form, they are bound to cellulose as protopectin. Mild acid hydrolysis of protopectin yields pectin or pectinic acid. Pectinic acids are colloidal, galacturonic acids containing more than negligible proportion of methyl ester groups. Pectins are water dispersible pectinic acids having varying methyl ester contents that are capable of forming gels with sugar and acid under suitable conditions. Pectic acids are composed mostly of colloidal polygalacturonic acids and are essentially free from methyl ester groups.

A linear chain of anhydro-D-galacturonic acid units is the basic structure of pectic substances. In an earlier section you have studied the structure of galactose. When the $-\text{CH}_2\text{OH}$ of a hexose is replaced by $-\text{COOH}$ it becomes an uronic acid. The chemical structures of some uronic acids are shown in Figure 3.5.

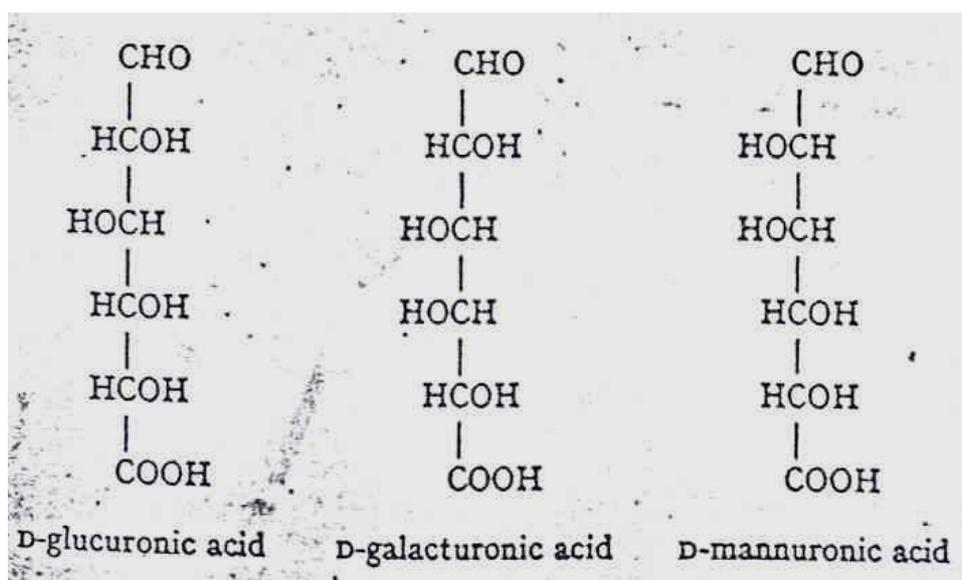


Figure 3.5: Uronic acids

A number of enzymes have been found to catalyse the various stages of pectin break down. You are familiar with softening of fruits during their ripening. It is due to the break down of pectin by the pectin degrading enzymes present in the fruits. There are two major types of pectin degrading enzymes. One is called pectin esterase (PE) or pectin methyl esterase (PME). This enzyme removes the methoxyl groups from the pectin molecules thereby reducing the viscosity of pectin solution and destroys its gelling property. The other enzyme is called polygalacturonase (PG), which breaks down pectinic acid chain into smaller fragments. For PG to act on pectin, the pectin molecule has to be initially demethylated to pectic acid by PME

Pectin as a jellifying agent: The most important use of pectin in food is based on its ability to form gels and it is therefore widely used in the manufacture of jams, jellies and marmalades. Depending on the degree (extent) of methylation (DM) of the carboxyl groups in pectin, they are classified into high and low methoxyl pectins (HMP and LMP). Generally, pectin having more than 50% methylated carboxyl groups (DM more than 50) are called high methoxyl pectin (HMP). HM pectins form gels with sugar and acid. For a good jelly, the sugar content should be in the range of 65–70% and pH 2.8 to 3.2. When the degree of methylation is below 50, the pectin is called low methoxyl pectin (LMP). Low methoxyl pectins form gels at a lower level of sugar but with divalent cations especially calcium. They can be gelled over a much wider pH range also. Therefore, LMP is used in preparing low sugar diabetic jams and jellies.

Citrus peel and pomace as well as apple pomace are good sources of pectin. Therefore, these raw materials are usually used for the manufacture of pectin.

Check Your Progress Exercise 2



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

1. What is the difference between cellulose and starch?

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2. What is the basic molecule in pectin?

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3. What is the difference between high and low methoxyl pectins?

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Gums: The term gum has been applied to many substances, both hydrophilic (water attracting) and hydrophobic (water repelling) that has gummy characteristics. Sometimes hydrophobic gums are called resins. Gums are essentially polysaccharides and are of plant and microbial origin.

Plant gums: Plant gums can be classified as seed gums, plant exudate gums and seaweed gums. They find wide food applications as stabilisers, thickeners, foam stabilisers, clarifying agents, flavour fixing agents, etc. Table 3.3 gives details of some vegetable gums used as food additives.

Table 3.3: Properties and use of some vegetable gums

| Name and Source | Properties |
|---|---|
| Seed gums Guar gum (<i>Cyamopsis tetra gonoloba</i>) Locust bean gum (<i>Ceratonia siliqua</i>) | Non ionic, heat stable, hydrates in cold water Like guar but heat required for maximum hydration and viscosity. |
| Plant exudate gums Gum Arabic (<i>Acacia senegal</i>) | Highly soluble, low viscosity, clear solution. |
| Seaweed extracts Agar (<i>Rhodophyceae</i>) Carrageenans (<i>Rhodophyceae</i>) Alginates (<i>Phaeophyceae</i>) | Forms strongest and most stable gel. Gels are transparent and reversible upon heating and cooling. Anionic, forms stable complexes with proteins and other gums. Anionic, widely variable viscosity properties in acid and salt, forms gels and films |

Microbial gums: Polysaccharides produced by microorganisms are finding wide food applications today. Dextran gums are produced by the action of micro-organisms like *Leuconostoc mesenteroides* on sugar syrup. They are readily soluble in water and have typical characteristics of a hydrocolloid like plant gums. Xanthan gum is produced by the action of *Xanthomonas campestris* on sugar containing medium. This gum consists of condensed D-glucose, D-mannose and D-glucuronic acid groups.

3.2.3 Chemical Reactions of Carbohydrates

Several of the chemical reactions of carbohydrates affect the food quality. During food processing operations, especially heat processing like sterilisation, cooking and dehydration, carbohydrates undergo several changes. Part of the non reducing sugars (like oligosaccharides) and polysaccharides hydrolyse to form reducing sugars. The carbonyl groups of the reducing sugars combine with the basic amino groups of proteins, peptides and amino acids to form sugar – amine compounds which undergo a series of reactions called Maillard reactions to produce dark coloured compounds and sometimes off flavour. This reaction is also referred to as non-enzymatic browning reaction to distinguish the enzyme mediated browning we observe, for example in cut fruits like apple where it is oxidation of some phenolic compounds.

Sugars alone in the absence of amino acids can also cause browning or blackening. At very high temperatures (above 100°C) reducing sugars condense with each other to form higher oligosaccharides and cyclic compounds. Such darkening reaction of sugars is called caramelisation.

Check Your Progress Exercise 3



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

1. Give three examples of plant gums.

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2. Explain microbial gums.

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3. Explain Maillard reaction.

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3.3 LIPIDS

Of the three most important nutrients, carbohydrates, proteins and edible fats, the latter belongs to a large class of very diverse substances called lipids. They can be classified into three main groups, their common property being that all contain fatty acids.

3.3.1 Occurrence and Classification

a) *Fats and oils:* They consist of triglycerol esters of fatty acids (designated here as F1, F2, F3) of the following general formula (Figure 3.6), which easily undergo hydrolysis forming glycerol and fatty acids.

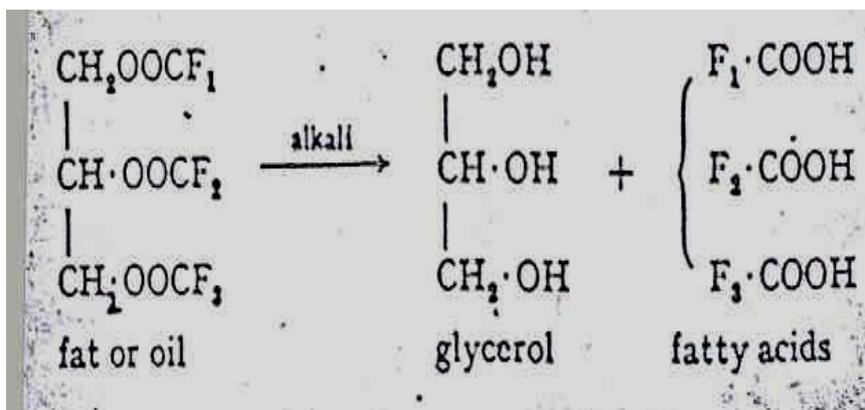


Figure 3.6: Alkali hydrolysis of fats and oils

Liquid fats are commonly referred to as oils.

- b) *Waxes*: They consist of fatty acids esterified by monohydric long chain alcohols such as myristyl alcohol (C30H61OH) in bees wax.
- c) *Phospholipids*: They are complex compounds in which glycerol or other alcohols are esterified partly by fatty acids and partly by phosphoric acid and by basic nitrogen compounds.

Lipids occur in all parts of plants and animal tissues. However, they are abundantly found in specific fat tissues, seeds and nuts (Table 3.4).

Table 3.4: Fat content of some foods

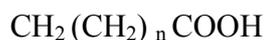
| Food | Fat (%) |
|-------------------------|---------|
| <i>Cereals</i> | |
| Maize | 3.6 |
| Rice | 0.6 |
| Wheat | 1.5 |
| Wheat germ | 7.4 |
| <i>Pulses</i> | |
| Bengal gram | 5.3 |
| Black gram | 1.4 |
| Green gram | 1.3 |
| Peas, dried | 1.1 |
| Soyabean | 19.5 |
| <i>Leafy vegetables</i> | |
| Amaranth | 0.5 |
| Cabbage | 0.1 |
| Drumstick leaves | 1.1 |
| <i>Nuts</i> | |
| Almond | 58.9 |
| Groundnut | 40.1 |
| Sesame seed | 43.3 |
| <i>Fruits</i> | |
| Apple | 0.1 |
| Avocado (Butter fruit) | 22.4 |

| | |
|-----------------------|------|
| <i>Seafoods</i> | |
| Bombay duck | 0.7 |
| Sardine (High fat) | 14.3 |
| <i>Meat</i> | |
| Poultry meat | 0.6 |
| Mutton | 13.3 |
| Egg (hen) | 13.3 |
| <i>Dairy products</i> | |
| Milk (cow) | 3.6 |
| Milk (buffalo) | 8.8 |

3.3.2 Fatty Acids

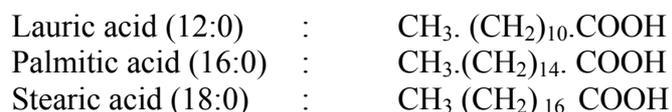
Even number straight chain saturated and unsaturated fatty acids make up the greatest portion of the fatty acids of the natural fats. The fatty acid composition of fats and oils has great bearing on human health.

Saturated fatty acids: These are straight chain acids with an even number of carbon atoms from C₂ to C₂₆. Their general formula is:

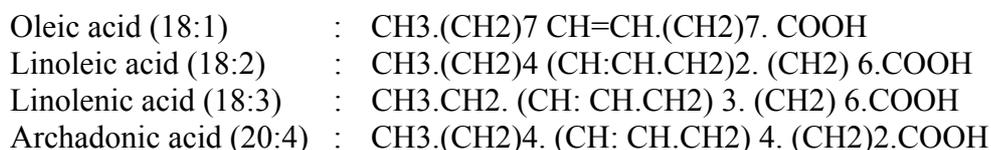


Where n is the number of – CH₂ groups.

The most widely distributed fatty acids in oils and fats are palmitic, lauric and stearic. It is customary to designate fatty acids by the number of carbon atoms they have. For example 16:0 refers to a fatty acid with 16 carbon atoms and zero refers to the number of double bonds (unsaturated carbon atoms). The chemical formulae of the three fatty acids are given below:



Unsaturated fatty acids: The most widely distributed unsaturated fatty acids in oils and fats are given below:



3.3.3 Properties of Fats and Oils

Lipids are water insoluble but soluble in organic solvents such as petroleum ether, hexane, chloroform etc. Certain physical and chemical properties of fats and oils help in identifying them. Fats do not melt sharply but soften over a range of temperatures and therefore melting point is not a very reliable technique to identify a fat. However, it provides some information on its identity. Different oils and fats have refractive indices with narrow variations. Therefore, refractive index measurement helps in testing the purity. Their smoke point, flash point and fire point characterizes fats and oils. The smoke point is the temperature at which a fat or oil gives off a thin bluish flame. The

flash point is the temperature at which the mixture of vapour with air will ignite and the fire point is the temperature at which the substance will sustain continued combustion.

Chemical properties: A number of chemical tests have been evolved to identify fats and oils and to detect adulteration. All oils and fats show some range of values and therefore sometimes more than one test is necessary.

Reichert–Meissl number: It is a measure of the amount of water soluble volatile fatty acids. It is defined as the millilitres of 0.1N alkali (such as potassium hydroxide) required to neutralise the volatile water soluble fatty acids in a 5g sample of fat. The common volatile water soluble fatty acids are butyric (C4) and caproic (C6) and caprylic (C8) acids. Reichert-Meissl number is particularly valuable in detecting adulteration in butter.

Saponification number: It is defined as the number of milligrams of potassium hydroxide required to saponify one gram of fat or oil. When potassium hydroxide reacts with a triglyceride, 3 moles of potassium hydroxide react with one molecule of fat. If the triglycerides contain low molecular weight fatty acids, the number of molecules present in 1 gram sample of fat will be greater than if the fatty acids have long carbon chains and higher molecular weights. The fats with the low molecular weight fatty acids will consequently have a higher saponification number. For example, butter with its unusually high percentage of butyric acid has the highest saponification number.

Iodine number: It is the number of grams of iodine absorbed by 100 g of fat. The double bonds found in the unsaturated fatty acid react readily with iodine or certain iodine compounds to form an addition compound even while the fatty acid is combined with glycerol in fat. The iodine number is therefore, a measure of the extent of unsaturation of the fatty acids in a fat.

Rancidity: We are familiar with the development of rancid smell in oils on storage. The process of auto oxidation and the resulting deterioration in flavour of fats and fatty acids are often described by the term ‘rancidity’. Temperature, moisture, the amount of air in contact with the oil or fat, light as well as the presence or absence of antioxidants influence rancidity development. Usually rancidity is referred to oxidative deterioration, but in many fats especially butter, rancidity refers usually to hydrolytic changes resulting from enzymatic activity. In general animal fats develop rancidity faster than vegetable or seed fats.

Oxidation of fats and oils is usually referred to as auto oxidation, because the rate of oxidation increases as the reaction proceeds. Fats and oils containing unsaturated fatty acids are generally susceptible for auto oxidation, though in practice deviations are possible due to the presence of natural antioxidants in them. The reaction products of auto oxidation of oils and fats are peroxides, hydroperoxides, aldehydes and short chain fatty acids which are responsible for the off flavour. **Peroxide value** of fats measures the extent of rancidity development. It is based on the amount of iodine released from potassium iodide by peroxides.

Lypolysis: Fats and oils also become rancid due to lypolysis. The ester linkages of lipids are subject to hydrolysis resulting from enzymes, heat, or chemical

reactions. These reactions are collectively known as lypolysis, lypolytic rancidity or hydrolytic rancidity. The free fatty acids that develop during storage and processing of oil seeds and animal tissues must be removed by a refining process. The lower free fatty acids being volatile by steam can be removed by steam distillation under vacuum while the remaining fatty acids are converted by means of sodium or potassium hydroxides into soaps by settling or centrifugation.

Antioxidants: Antioxidants are nothing more than substance with preferential ability to oxidize namely certain compounds, which will oxidize prior to the substances that are being protected. They are both water soluble and fat soluble. For protecting fats, oils and fatty foods, fat-soluble antioxidants are required. Butylated hydroxy anisole (BHA), Butylated hydroxy toluene (BHT) and esters of gallic acid are common antioxidants for this category of foods. Many naturally occurring substances also function as antioxidants. Most prominent are tocopherols. Their presence in natural vegetable oils is the cause for stability of such oils.

Hydrogenation: The physical requirement of many fats used in foods is generally different from those of natural fats and oils. Hydrogenation, the direct addition of hydrogen to double bonds of fatty acids is used to modify vast quantities of fats and oils. Vanaspati is an example of hydrogenated fat. Close control of hydrogenation results in highly specific results. For example, salad and cooking oils can be improved by controlled hydrogenation. Hydrogenation of fats and oils is achieved by mixing them with hydrogen at elevated temperature in the presence of a suitable catalyst, the most common being nickel.

Check Your Progress Exercise 4



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

1. Give an example of a fruit containing high level of fat.

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2. What are the hydrolysis products of fats and oils?

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3. What is the difference between saturated and unsaturated fatty acids? Give two examples for each.

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4. Define Reichert-Meissl number and iodine number of fats and oils.

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3.4 LET US SUM UP

Carbohydrates are widely distributed in nature. They are grossly classified into monosaccharides, oligosaccharides and polysaccharides. Simple sugars like glucose and fructose are monosaccharides. Sucrose (cane sugar) is the most important disaccharide.

Unlike monosaccharides and oligosaccharides, polysaccharides like cellulose and starches are insoluble in water. Both cellulose and starches are made up of glucose units, but differ in their number of glucose units and their nature of bonding.

Sugars undergo browning reactions during processing and storing. Nonenzymatic browning reactions (Maillard reactions) are initiated mainly due to the reaction between reducing sugars and their amino acids.

Plant gums are also a class of polysaccharides. They have many food and industrial applications.

Lipids are distributed widely in plant and animal foods. They are classified into oils and fats, waxes and phospholipids. Oils and fats on hydrolysis yield fatty acids and glycerol. Fatty acids can be saturated or unsaturated. There are different methods to find out the degree of unsaturation in fats and oils. Unsaturated fatty acids in fats and oils are responsible for rancidity development. Adding antioxidants to fats and oils and fatty foods can prevent development of rancidity.

3.5 KEY WORDS

- Monosaccharides** : Simple sugars or monoses, readily soluble in water and most of them are sweet to taste.
- Hexoses** : Six carbon sugars like glucose and fructose.
- Oligosaccharides** : Water soluble polymers of a few condensed monosaccharides.
- Disaccharides** : Polymers of two condensed monosaccharides like sucrose, maltose and lactose.
- Degree of sweetness (DS)** : Sweetness scale in which sweetness of sucrose is assigned the number 100. Fructose has DS of 173.3 and saccharin 30,000 to 50,000.

- Polysaccharides** : Polymers of simple sugars having high molecular weights. Examples are cellulose and starch.
- Pectic acid** : Unmethylated poly galacturonic acid.
- High and low methoxyl pectins** : Pectic acid in which more than 50% of the carboxyl groups are methylated and in which less than 50% carboxyl groups methylated are called high and low methoxyl pectins respectively.
- Gums** : Complex polysaccharides of plant and microbial origin having gummy characteristics.
- Maillard reaction** : Reaction between reducing sugars and amino acids leading to brown compounds.
- Rancidity** : Development of rancid odour in oils and fatty foods on storage.

3.6 ANSWERS TO CHECK YOUR PROGRESS EXERCISES



Check Your Progress Exercise 1

Your answers should include the following points:

1. Simple sugars, polymers of few monomers, water soluble, sweet. Polymers of simple sugars of large molecular weight.
2. Glucose, fructose, mannose, sorbose.
3. Rotation of plain polarised light.
4. Amygdaline, naringin.
5. Sucrose, maltose, lactose.
6. Sucrose hydrolysis, fructose sweeter than glucose.

Check Your Progress Exercise 2

Your answers should include the following points:

1. α and β linkages, degree of polymerisation.
2. Galacturonic acid
3. Degree of methylation of pectic acid.

Check Your Progress Exercise 3

Your answers should include the following points:

1. Guar gum, gum Arabic, carrageenans.
2. Xanthan, dextran.
3. Sugar – amino acid reaction.

Check Your Progress Exercise 4

Your answers should include the following points:

1. Avocado
2. Glycerol and fatty acids
3. Double bonds, palmitic, stearic, oleic, linolenic
4. Water soluble volatile fatty acids
5. Degree of unsaturation
6. Oxidation of unsaturated fatty acids

3.7 SOME USEFUL BOOKS

1. Owen R. Fennema, (1976) Principles of food science, Part I-Food Chemistry, Marcel Decker Inc.; New York.
2. Meyer L.H. (1969) Food Chemistry, Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.
3. Braverman, J.B.S. (1963) Introduction to the Biochemistry of foods, Elsevier Publishing Company, Amsterdam, London, New York.