UNIT 8 LIPIDS

Structure

8.0 OBJECTIVES

After studying this Unit we shall be able to:

- state the composition and sources of lipids in nature;
- classify lipids into various groups on the basis of their structure and properties;
- draw the basic skeletal structures of molecules constituting lipids;
- explain the physical, chemical and functional properties of lipids; and
- describe the role of lipids in foods and nutrition.

8.1 INTRODUCTION

What adds taste and flavour to all cooked foods, especially the fried foods? We all know that it is due to oils and fats to some extent. Both of these belong to a class of organic compounds called lipids. Lipids are also important constituents of food which are hydrophobic in nature i.e., water hating and do not mix with water. These consist of a group of structurally diverse molecules.

Lipids along with proteins and carbohydrates constitute the principal structural components of all living cells. Some of these are important energy storage compounds especially in animals and human beings. During the past few decades, role of lipids in diet has come into focus due to their connection with blood cholesterol and consequently heart diseases. They exhibit unique physical and chemical properties which play a significant role in their diverse functional properties.

Lipids undergo complex chemical changes during processing, storage and handling of foods. In order to understand these changes it is important to learn about their types, structure and the properties. In view of this, the present Unit deals with classification, structure and properties of lipids. Food application and nutritional aspects of these molecules are also dealt with.

8.2 OCCURRENCE AND SOURCES

Lipids represent a heterogeneous group of substances of plant or animal origin that vary in their structure and composition. These include a wide range of compounds like oils, fats, waxes, sex hormones, cholesterol etc. As mentioned before, lipids are insoluble in water and identified by their solubility only in organic solvents like ether, chloroform, benzene etc. Their insolubility in water is a common observation in the household while working with oil and *ghee*. The natural foods that contribute to the largest amount of the lipids or fats are animal products, e.g., meats, milk, egg, etc. Animals store fat in adipose tissues from which it can be extracted. Some of the animal sources and the type of fat present in them are given in Table 8.1.

Table 8.1: Some Fats from Animal Sources

S.No.	Animal Source	Type of Fat
1.	Mammals like cetaceans and pinnepeds	Blubber (vascular fat)
2.	Liver of cod (a type of fish)	Cod liver oil
3.	Pig (pork)	Lard
4.	Beef	Tallow (rendered fat)
5.	Chicken	Chicken fat
6.	Milk	Butter, Ghee

Most cereals, vegetables and fruits contain very little fat. However, some of the fruits and vegetables like grain corn, avocado and the fruit palm are also rich sources of these compounds contrary to the notion of the absence of fats in these. Table 8.2 lists some common food sources and the percentage of fats present in them.

Table 8.2: Fat content of some foods

S.No.	Food	Fat (%)
1	Maize	3.6
2	Rice	0.6
3	Wheat	1.5
4	Wheat germ	7.4
5	Bengal gram	5.3
6	Black gram	1.4
7	Green gram	1.3
8	Peas, dried	1.1
9	Soybean	19.5
10	Amaranth	0.5
11	Cabbage	0.1
12	Drumstick leaves	1.1
13	Almond	58.9
14	Groundnut	40.1
15	Sesame seed	43.3

S.No.	Food	Fat (%)
16	Apple	0.1
17	Avocado(Butter fruit)	22.4
18	Bombay duck (fish)	0.7
19	Sardine (high fat)	14.3
20	Poultry meat	0.6
21	Mutton	13.3
22	Egg (hen)	13.3
23	Milk (cow)	3.6
24	Milk (buffalo)	8.8

Some plants store fat in their seeds e.g., oil seeds and nuts. The largest sources of vegetable oils are the seeds of annual plants such as soybean, cotton seed, peanut, linseed, sunflower, safflower, mustard and rapeseed. Other sources of vegetable oils are the oil bearing fruits and nuts of trees such as coconut palm, oil palm and olive. Oil content for different vegetable oil sources varies from 18% to 68% of the total weight of the seed, nut kernel or fruit, as shown in Table 8.3.

Table 8.3: Oil Content of Few Vegetable Oil Sources

S.No.	Vegetable Oil Source	Oil Content (%)
1	Coconut	65 – 68
2	Cottonseed	18 – 20
3	Olive	25 – 30
4	Palm	45 – 50
5	Palm kernel	45 – 50
6	Peanut	45 – 50
7	Safflower	30– 35
8	Soybean	18 – 20
9	Sunflower	35 – 45
10	Mustard	28.76g/100g
11	Linseed(flax)	~ 40

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) Arrange the following foods in the increasing order of their fat content. Cow milk, Amaranth, Soybean, Almonds, Egg, Sardine fish

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

8.3 CLASSIFICATION OF LIPIDS

As mentioned earlier, lipids consist of a group of molecules having diverse structures. Food lipids are consumed in the form of visible and invisible fats. **Visible fats** are called so because these are the fats that can be seen by us after these are separated from the original plant or animal source, e.g. vegetable oils, butter, etc. **Invisible fats** are constituents of basic foods as present in milk, cheese, meat etc. and are consumed without being separated.

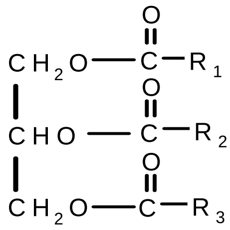
On the basis of their structure, lipids are generally classified into three main classes. These are as given below:

- simple lipids
- complex lipids
- derived lipids

Let us understand their different features.

8.3.1 Simple Lipids

Chemically, simple lipids are esters of fatty acids with alcohols. You will read in detail about the fatty acids in Sec. 8.4. Oils and fats are common examples of this class of lipids which are the esters of long chain fatty acids with glycerol. These esters called **triglycerides** or **triacylglycerols**, compose one of the major food groups of our diet. The triglycerides that are solids or semisolids at room temperature are classified as **fats** and occur predominantly in animals. These are generally the triglycerides containing saturated fatty acids. On the other hand the triglycerides that are liquids are called **oils.** These originate primarily in plants; however triglycerides from fish are also largely oils. These are the esters of unsaturated fatty acids with glycerol.



A Triglyceride

Waxes are also simple lipids and are esters of fatty acids with long chain monohydric alcohols. These are widely distributed in nature. For example, the leaves and fruits of many plants have waxy coatings, which protect them from dehydration and small predators. The feathers of birds and the fur of some animals have similar coatings which serve as a water repellent. Waxes are usually inert due to the saturated nature of the hydrocarbon chain. Carnauba wax obtained from carnauba palm of Brazil is an example of a tough and water resistant wax. It contains esterified fatty dialcohols (diols, about 20%), hydroxylated fatty acids (about 6%) and cinnamic acid (about 10%). Rice bran obtained from milling of rice contains a wax mixed with triglycerides.

$CH_3(CH_2)_{14}COO{-}(CH_2)_{15}CH_3$

Spermaceti wax

$CH_3(CH_2)_{24}COO{-}(CH_2)_{29}CH_3$

Bees wax

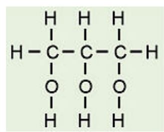
$CH_3(CH_2)_{30}COO{-}(CH_2)_{33}CH_3$

Carnauba Wax

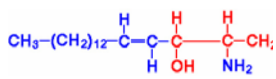
8.3.2 Complex Lipids

Complex lipids are also esters of fatty acids with alcohol. However, in addition to these two components they contain other groups, such as a phosphate group or a carbohydrate moiety. Depending upon the moiety attached, this group comprises of the following types of lipids.

a) Phospholipids: These complex lipids contain a phosphate group, in addition to fatty acids and an alcohol. They frequently have nitrogen containing bases and other substituents as well. Phospholipids that contain glycerol as the alcohol are known as **glycerophospholipids** and those having sphingosine as the alcohol moiety are called the **sphingophospholipids.**

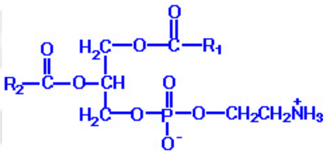


Glycerol

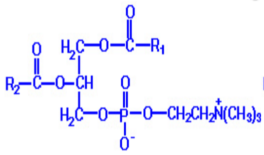


Sphingosine

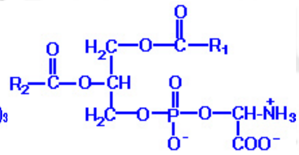
Phosphatidylethanolamine (**PE**), phosphatidylinositol (**PI**), phosphatidylserine (**PS**), and phosphatidylcholine (**PC**) are important phospholipids found in dairy products. Whereas sphingomyelin (**SM**), glucosylceramide (**GLUCER**), and lactosylceramide (**LACCER**) are important dairy sphingolipids.



Phosphatidylethanolamine (PE)



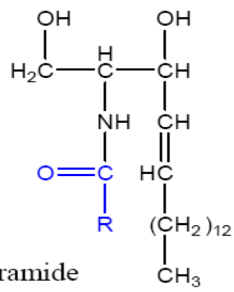
Phosphatidylcholine (PC)



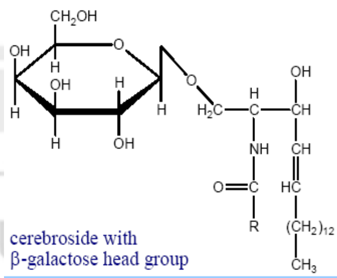
Phosphatidylserine (PS)

The biological membrane of native milk fat globules consists of about one-third phospho and sphingolipids, stabilizing the milk fat globules in the serum phase of the milk. In recent years, phosphor and sphingolipids have received renewed interest because of the positive biological effects. They are found to have an ability to reduce blood cholesterol and to enhance brain functioning. Besides, these also have good anti-oxidative and bacteriostatic properties.

b) **Glycolipids**: These lipids contain a carbohydrate group, in addition to fatty acids and an alcohol. The sugar group in glycolipids is usually galactose though sometimes these may contain glucose. The alcohol part is either sphingosine or glycerol. Sphingolipids are derivatives of sphingosine, which has a long hydrocarbon tail, and a polar domain that includes an amino group. The amino group of sphingosine can form an amide bond with a fatty acid carboxyl, to yield a ceramide. A ceramide with a monosaccharide like glucose or galactose as polar head group is called cerebroside.



ceramide



cerebroside with β-galactose head group

Prostaglandins are naturally occurring carboxylic acids derived from the parent C_{20} acid called prostanoic acid. These are widely distributed in the mammalian tissues and perform many vital functions in the biological processes like inflammatory response, production of pain etc.

The cerebrosides are common constituents of membranes of animals and plants. For example, galactosylceramide is the principal glycosphingolipid in brain tissue and myelin. Some glycolipids are involved in the antigenicity of blood group determinants, while others bind to specific toxins or bacteria.

c) **Other complex lipids**: The category comprises of lipids such as, sulpholipids, aminolipids and lipoproteins, containing sulphur, amino and protein molecules respectively attached to these.

8.3.3 Derived Lipids

It is another major class of lipids. These are obtained from the complex lipids by hydrolysis and include fatty acids (saturated as well as unsaturated), glycerol, steroids, lipid soluble vitamins i.e. A, D, E and K and prostaglandins. Another way of looking at derived lipids is that these are all those lipids which do not belong to the simple and complex lipid categories.

The flow chart indicating classification of lipids can be depicted as below.

- Simple
  - Fats
  - Oils
  - Waxes
- Complex
  - Phospholipids
  - Glycolipids
  - Other complex lipids
- Derived
  - derived from simple and complex lipids

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) Fill in the blank spaces in the following with appropriate words.

i) Simple lipids are constituted of ………………… and ………………..

ii) Chemically simple lipids are also called ……………………………..

iii) Fats, oils and waxes have a similar chemical constitution and are categorised as …………………………… lipids.

iv) Steroids belong to the class of ……………………….. lipids.

v) Lipids containing a carbohydrate moiety are called……………………

8.4 STRUCTURE OF LIPIDS

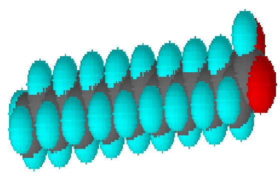
You have read in Units 6 and 7 that carbohydrates and proteins are large polymeric molecules consisting of repeating monomeric units. Unlike carbohydrates and proteins, lipids do not have repeating monomeric units i.e. these are not polymeric in nature. You now know that simple lipids are chemically esters of fatty acids but what is the structure of fatty acids? Let us first learn about that.

Carboxylic group

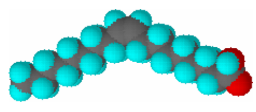
$CH_3(CH_2)_n$ COOH

Hydrocarbon chain

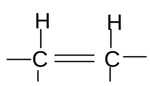
A Fatty Acid



Saturated Fatty Acid



Unsaturated Fatty Acid

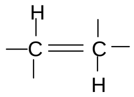


***cis* isomer**

8.4.1 Fatty Acids

Fatty acids are long chain hydrocarbons containing a terminal carboxyl group. These normally occur as their esters in natural fats and oils. However, they do occur in the unesterifed form as fatty acids bound to certain proteins. Most of the fatty acids, especially those which occur in natural fats, contain an even number of carbon atoms; usually more than 14 carbon atoms. While most of the fatty acids have either 16, 18 or 20 carbon atoms, fatty acids with lesser number of carbon atoms (4-8) are present in milk fat, whereas those of intermediate chain length (10-14), and between 16-20 carbon atoms are found in most of the animal and vegetable fats.

The hydrocarbon chain of the fatty acids is either saturated, i.e., without any double bond or unsaturated, i.e., with one or more double bonds. Respectively these are called **saturated** or **unsaturated fatty acids**. A fatty acid with a single double bond is called **monounsaturated fatty acid (MUFA);** when it contains two or more double bonds then it is called as a **polyunsaturated fatty acid (PUFA)**. MUFA is obtained primarily from plant sources, such as Safflower or kardi oil (13% MUFA), canola (62% MUFA), peanut (49% MUFA) and olive (77%). Olive oil has the highest content of MUFA among most vegetable oils. MUFA is also found in olive oil margarine, canola margarine, and peanut butter. The natural sources of PUFA are nuts and seeds. Cold water fishes like salmon also contain a good amount of PUFA.



Trans isomer

Unsaturated fatty acids exhibit geometric isomerism. Geometric isomerism isomeric is depicted due to the presence of one or more double bonds. The orientation of two hydrogen atoms attached to the carbon atoms joined by double bond may differ. If both the hydrogens are on the same side it is called a *cis*_isomer. When they are on either side of double bond, a *trans* isomer is formed. Nearly all naturally occurring unsaturated fatty acids have a *cis* configuration.

Some of the common saturated and unsaturated fatty acids with their sources are given in Table 8.4.

Table 8.4: Some saturated and unsaturated fatty acid

S.N	Common name	Systematic name	Structure	Source
1.	Butyric acid	n-Butanoic acid	$CH_3(CH_2)_2COOH$	Butter
2.	Caproic acid	n-Hexanoic acid	$CH_3(CH_2)_4COOH$	
3.	Palmitic acid	n-Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	Present in all animal and plant fats
4.	Stearic acid	n-Octadecanoic acid	$CH_3(CH_2)_{16}COOH$	Animal fats and plant oil
5.	Arachidic acid	n-Eicosanoic acid	$CH_3(CH_2)_{18}COOH$	Ground nut oil
6.	Palmitoleic acid	Hexadec-9- enoic acid	$CH_3(CH_2)_5CH = CHCH_2)_7COOH$	All fats
7.	Oleic acid	Octadec-9-enoic acid	$CH_3(CH_2)_7CH = CHCH_2)_7COOH$	All fats, abundant in olive oil
8.	Linoleic acid	Octadeca-9:12-dienoic acid	$CH_3(CH_2)_4(CH=CH.CH_2)_2 (CH_2)_6 COOH$	Sunflower oil, corn oil etc.
9.	Linolenic	Octadeca-9:12:15 trienoic acid	$CH_3(CH_2)_3(CH=CH.CH_2)_3 (CH_2)_6 COOH$	Flax seeds, hemp seeds etc.
10.	Arachidonic acid	5: 8:11: 14-Eicosa-tetraenoic acid	$CH_3(CH_2)_4(CH = CHCH_2)_4(CH_2)_2COOH$	Peanut oil, groundnut oil

The numbers in the names as given in Table 8.4 indicate the positions of double bonds. How do you ascertain these positions? Let us learn the nomenclature of fatty acids.

Nomenclature of Fatty Acids

Fatty acids are generally named after the parent hydrocarbon, by substituting -oic in place of –e in the name of the hydrocarbon. For example, the fatty acid ($CH_3 – (CH_2)_6 – COOH$) derived from octane is octanoic acid. Similarly, the unsaturated fatty acids with double bonds end in –enoic acid, for example, octadecenoic acid ($(CH_3) – (CH_2)_7 – CH = CH – (CH_2)_7 – COOH$). In the complete name of the fatty acid the number and position of unsaturation, if any, needs to be specified. For this purpose, the carbon atoms are numbered starting from the carboxyl carbon giving it number 1. In another labeling scheme, the carbon atom adjacent to the carboxyl carbon is sometimes called α-carbon; the next as β and so on; the terminal methyl carbon is known as the *ω*-carbon or **n**-carbon atom. For indicating the number and position of the double bonds in unsaturated fatty acids, various conventions are used. For example, Δ^9 indicate a double bond between carbon atoms 9 and 10 in the hydrocarbon chain. Similarly, *ω*-9 indicates a double bond on the 9th carbon atom, counting from the *ω*-carbon. Let us take the example of oleic acid to understand this.

The structural formula of oleic acid is $^{18}CH_3(CH_2)_7{}^{10}CH = {}^9CH(CH_2)_7{}^1COOH$

Oleic acid is designated as 18:1; 9 or 18:1; Δ^9 suggesting that it has a carbon chain of **18** atoms and has **one** double bond at **ninth** carbon, counting from the carboxyl carbon. Alternatively, the carbon atoms in oleic acid can be numbered in the following manner.

$$\overset{1}{\underset{\omega}{}}CH_3^2CH_2^3CH_2^4CH_2^5CH_2^6CH_2^7CH_2^8CH_2^9CH = CH(CH_2)_7COOH$$

It is represented as *ω*-9, C18:1 or n-9, C 18:1. Here, the carbon atom 9 is counted from the *ω* carbon. The digit 1 after 18 in both the representations denotes one unsaturated bond in the molecule.

Essential Fatty Acids

Some of the PUFAs, such as linolenic, linoleic and arachidonic acids are not synthesized by higher animals and man. These have to be supplied through dietary sources, as they are essential for normal health and well being of the organism. Such fatty acids are known as **essential fatty acids (EFA)**. Two fatty acids are essential to human health. The first is a *ω*-6 fatty acid called linoleic acid (LA); found abundantly in safflower, sunflower, corn and evening primrose oils. The second, a *ω*-3 fatty acid called alpha-linolenic acid (LNA) or ALNA, is found abundantly in olive, flax seeds, hemp seeds, walnuts, soybeans, and freshly ground wheat germ.

Composition of some vegetable oils in terms of the main saturated and unsaturated fatty acids is given in the Table 8.5. The oils rich in PUFA are considered good for health. Study Table 8.5 and guess the good quality oil among all given.

Table 8.5: Composition of Some Vegetable Oils

S.No.	Sources of Oil	Saturated Fatty Acids			Unsaturated Fatty Acids		
		Palmitic	Stearic	Arachidic	Oleic	Linoleic	Linolenic
1	Cottonseed	22	3	Tr	19	54	1
2	Peanut	11	2	2	48	32	-
3	Sunflower	7	5	-	19	68	-
4	Corn	11	2	Tr	28	58	-
5	Sesame	9	4	-	41	45	-
6	Olive	13	3	Tr	71	10	1
7	Palm	45	4	-	40	10	-
8	Soybean	11	4	Tr	24	54	7
9	Safflower	7	2	Tr	13	78	-
10	Mustard	3.5	-	-	22.4	24.4	13.7

Now you will read how the fatty acids and glycerol combine to form ester i.e., the triglycerides or the acyglycerols. Before that let us review what all we have learnt in subsection 8.4.1.

Check Your Progress Exercise 3

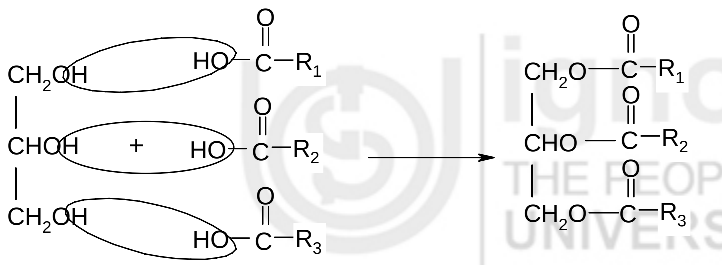
Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

Tick mark(√) the correct answer for the statement given below.

1) The essential fatty acids are called so because,
i) these are essential component of lipids.
ii) these are not synthesised by our body and are essential for normal growth.
iii) these contain unsaturated hydrocarbon chain.
iv) these are constituents of all fats and oils.

8.4.2 Acylglycerols

Acylglycerols are the most abundant group of naturally occurring lipids. These are the esters of fatty acids with a trihydroxy alcohol i.e. glycerol. The reaction between a fatty acid and glycerol during esterification can be shown as below.



One, two or all the hydroxyl groups of glycerol can undergo esterification to yield **mono** -, **di** -, and **triacylglycerols**, respectively. Triacylglycerols, the so called neutral fats as they do not carry a charge, are also known as **triglycerides**. The general structures of the three acylglycerols, wherein R, R and R represent the fatty acid residues is illustrated in Fig. 8.1.

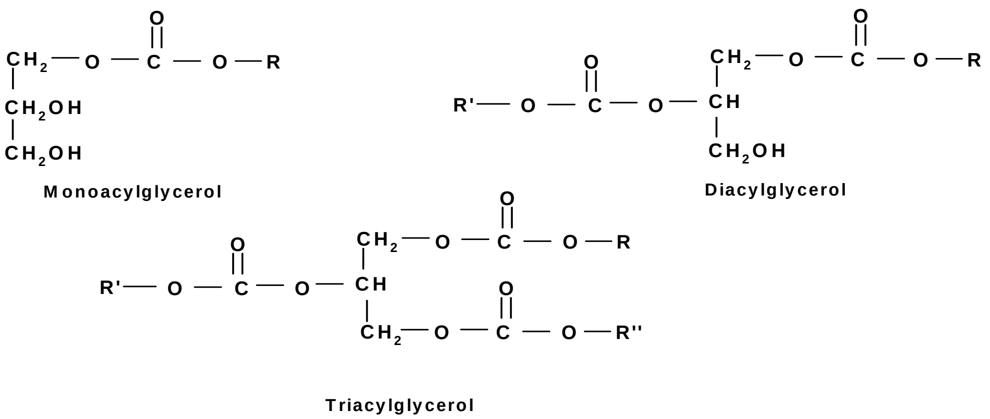


Fig. 8.1: Structures of mono-, di- and triacylglycerols

While most of the naturally occurring acylglycerols are triacylglycerols, the mono-and diacylglycerols are formed as intermediates in the metabolism of lipids. Triacylglycerols from animal sources normally contain a higher percentage of saturated fatty acids and are solids at room temperature. These are generally solids while those from vegetable sources are rich in unsaturated fatty acids, and remain generally in liquid form at room temperature. These are called oils as you have studied in Sec 8.3.

Trans Fatty Acids

The unsaturated fatty acids (MUFA and PUFA) found in vegetable oils are generally liquids at room temperature. The liquid vegetable oils can be converted into a solid or semi-solid by hydrogenation. In the process of partial hydrogenation, the chemical structure of the natural fatty acid is changed from their original *cis*- configuration to unnatural *trans*- configuration and we get what are called ***trans*-fatty acids**. These don't get spoilt easily and can also withstand repeated heating. This is attractive characteristics for food makers especially for those commercially engaged in baked goods and snack foods. However, a strong relationship is found between the consumption of *trans* fatty acids and heart disease. While *trans* fatty acids may be classified as hydrogenated polyunsaturated fats due to their chemical structure, they generally are like saturated fats in terms of their health effects.

Naturally occurring trans-fat is very rare; a small amount is found in cow milk due to the bacteria in the gut of dairy cows.

Most margarines, vegetable shortening, partially hydrogenated vegetable oil, deep-fried chips, many fast foods, commercially available baked goods are the sources trans fatty acid foods.

Shortening is the fat used for making cake or pastry light or flaky.

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.

Tick mark (√) the correct answer for the statement given below.

1) The fats and oils can be differentiated on the basis of which of the following?
i) The source from which these are separated
ii) The hydrocarbon chain attached to the fatty acid
iii) Extent of unsaturation in the fatty acids constituting them.
iv) The hydrocarbon chain attached to the alcohol.

8.5 PROPERTIES OF LIPIDS

The physical and chemical properties of fats are found to depend mainly on their composition. A number of these properties are made use of in identification and ascertaining their purity. Their physical properties help in identifying the utility of a fat for some specific purpose and in determining the stage of processing. Let us know their physical properties first.

The fats are plastic in nature i.e. are soft, can be deformed, do not flow and can be spread e.g. butter.

8.5.1 Physical Characteristics

Contrary to the common belief, pure oils and fats are colourless, odourless and tasteless. The colours and flavour of the fats are a result of the presence of the substances that dissolve in them. Fats and oils are lighter (densities are about 0.8 to 0.9 gm^3) than water and are poor conductors of heat and electricity. Some of the common physical properties of oils and fats are discussed below:

You would recall that an **emulsion** is a heterogenous system consisting of at least one immiscible liquid dispersed in another in the form of droplets. The phase present as fine droplets is called the **disperse** or the **discontinuous** phase while the one in which these droplets are suspended is called the **continuous** phase.

Emulsification

What happens when oil is mixed with water? You know that the fats are insoluble in water and form two layers on mixing and shaking. However, they can form emulsions in the presence of emulsifying agents. The emulsion can be **oil in water** type: e.g. milk, cream, mayonnaise and salad dressings. It can be **water in oil** type where water gets dispersed in oil (e.g. butter). Surface active agents that are added to help in emulsification are called **emulsifiers** or **emulsifying** agents.

The emulsification of fats is a necessary step in a number of food products such as cakes, ice-cream and other frozen desserts. Some of the common natural food emulsions are milk, cream and egg-yolk

Melting point

The consistency of a fat depends on how it has been obtained i.e. whether it is obtained by gradual or sudden cooling of the oil. However, if kept for sufficient time, it equilibrates and becomes reasonably consistent.

Fats do not give a sharp melting point like other organic compounds. Instead they soften over a range of temperatures. The melting point of a fat also depends on its previous heating-cooling history. This has been attributed to the phenomenon of **polymorphism** i.e. existence of fats in different crystalline forms. Another factor responsible for the absence of sharp melting point of fats is that they consist of mixtures of glycerides each with its own characteristic melting point.

The melting point of fats does not imply the same characteristics that it does for pure crystalline substances.

In general, the fats which contain relatively large amount of unsaturated fatty acids have relatively low melting points and are usually oils at room temperature. The fats with large amount of saturated fatty acids have higher melting points. Some related terms are explained as follows:

***Softening point*:** The temperature at which an equilibrated solid fat, filled in a capillary tube, starts rising on slow heating indicates its *softening point*. The softening point can be used to characterise some fats.

Slipping point: It is an empirical characteristic of fats and is related to the composition of a fat and also air or water embedded into the fat during its manufacturing process. To measure it, small brass cylinders filled with the solid fat, are suspended in a bath close to the thermometer. The temperature of the bath is slowly raised by stirring. The temperature, at which the fat rises in the cylinder or slips, is called as the *slip point.*

Shot melting point: It is the temperature at which a small lead shot will fall through a fat sample. Thus, for fats the melting point is defined by the specific conditions of the method by which it is determined.

Specific Gravity

The specific gravity of fats is found to depend to some extent on the degree of unsaturation and the chain length of the fatty acid. Since the nature of fats is such that they are sensitive to temperature, the specific gravity is usually measured at 25°C. However, for high melting fats a higher temperature of 40°C or even of 60°C may be required.

Refractive Index

You know that the refractive index refers to the deflection of a beam of light when it passes from one transparent medium to another. It is defined as the ratio of velocity of light in vacuum to the velocity of light in the oil or fat. Generally, it is expressed as the ratio of the sine of angle of incidence to the sine of angle of refraction when a ray of light of known wave length passes from air into the oil or fat. It is measured with the help of Abbe's or Butyro refractometer. When butyro refractometer is used, its reading (called **B.R. Reading)** is converted to refractive index with the help of suitable conversion tables. As refractive index varies with temperature and wavelength, the temperature is maintained during the measurements. The refractive index of fats can be used for their identification and also for testing their purity. The refractive index of fats is found to increase with increase in length of the carbon chains and also with the number of double bonds in it.

Smoke, Flash and Fire points

Smoke point is the temperature at which a fat or oil gives off bluish smoke on heating in an open vessel. The *flash point* is the temperature at which the mixture of fat vapours with air gets ignited and the *fire point* is that temperature at which the fat sustains a continued combustion. For a given sample of oil or fat, the temperature is progressively higher for the smoke point, flash point and fire point. These are found to depend on the amount of free fatty acids in the fat. However, the degree of unsaturation has little effect on them. These are particularly useful in connection with fats used for any kind of frying. The smoke, flash and fire points of some fats are given in Table 8.6.

Table 8.6: The Smoke, Flash and Fire Points (in ^{o}C) of Some Fats

Fat/ Oil	Smoke Point	Flash Point	Fire Point
Castor, refined	200	298	335
Corn, crude	178	294	346
Corn, refined	227	326	359
Olive	175-199	321	361

Turbidity Point

It is the temperature at which turbidity appears in a solution of fat on cooling. It is determined by warming a mixture of oil and solvent in which it has limited solubility till it dissolves and slowly cooling it till the oil separates out and turbidity appears. A number of different solvents have been employed to determine the turbidity point. The turbidity points are found to be sensitive to the presence of free fatty acids. This test has utility in differentiation of different fats and helps in detection of adulteration.

Try to check your understanding by answering the following exercise before proceeding to the chemical characteristics of lipids.

Check Your Progress Exercise 5

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

1) Match the statements given in column 1 with the terms given in column 2 correctly.

Column 1		Column 2	
a)	An example of a natural food emulsion	i)	Refractive index
b)	A fat can be identified by measuring this property	ii)	Turbidity point
c)	Increase in this property with increase in saturation	iii)	Milk
d)	Measuring this property of fats help detecting adulteration	iv)	Melting point

8.5.2 Chemical Reactions and Fat Constants

The chemical reactions of fats depend on their composition and the nature of their constituents. A number of tests based on the determination of the chemical composition have been developed to serve as tools to identify, differentiate and also to check for the purity of oils and fats. The characteristic parameters that are used for identification of oils and fats are sometimes called as fat constants. Some of the common chemical reactions of oils and fats and the tests based on these are discussed below.

The saponification value is an index of mean molecular weight of the fatty acids of glycerides comprising a fat.

Butter with high percentage of butyric acid has the highest saponification value.

Butter fat contains mainly the glycerides of butyric acid which is volatile and water soluble. As no other fat contains butyric acid glycerides, the Reichert-Meissl value of the butter fat is higher than that for any other fat.

As coconut oil and palm kernel oil contain appreciable quantities of steam volatile but water insoluble caprylic, capric and lauric acid glycerides, these have high Polenske value.

Saponification

Oils and fats when boiled with alcoholic solution of NaOH or KOH undergo hydrolysis into glycerol and fatty acids. Since the sodium or potassium salts of fatty acids so obtained act as soaps, the reaction is known as '**saponification'.** The number of milligrams of potassium hydroxide required to saponify 1g of the oil or fat is called its **saponification number or saponification value**. This number is a measure of the size of the fatty acid chains. A larger value indicates that the fat contains short chained or low molecular weight fatty acids whereas the fats containing long chained fatty acids would have a low saponification value.

Reichert-Meissl and Polenske Values

Butter is different from other fats as it contains the glyceryl esters of relatively low molecular weight fatty acids, primarily butyric acid and caproic, capric, caprylic, lauric and myristic acids. These fatty acids are wholly or partially steam volatile and water soluble. The **Reichert-Meissl Value** is a measure of water soluble steam volatile fatty acids mainly butyric and caproic acids present in oil or fat. It is defined as the number of millilitres of 0.1N aqueous sodium hydroxide solution required to neutralise the steam volatile water soluble fatty acids obtained by distillation of 5g of an oil-fat under the prescribed conditions.

The **Polenske Value**, on the other hand is a measure of the steam volatile and water insoluble fatty acids, like caprylic, capric and lauric acids present in oil or fat. It is defined as the number of mili litres of 0.1N aqueous alkali solution required to neutralize steam volatile water insoluble fatty acids obtained by the distillation of 5g of the oil-fat under the prescribed conditions

As you know, butter contains butyric acid as the main water soluble volatile fatty acid. The butyric acid content of a fat can be determined in terms of **Kirschner value (K-Value)**. The K-value determination exploits the fact that the silver salt of butyric acid is soluble in water while that of other fatty acids are insoluble. To determine the K-value, the neutralized R.M. distillate is treated with silver sulphates and filtered. The silver acidified butyrate then distilled and determined by titrating against standard alkali.

The K-Value determination is useful in differentiating between butter and coconut oil or for detecting adulteration of butter.

Halogenation

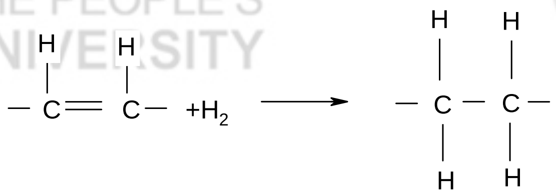
The unsaturated fatty acids in free or combined state readily accept halogens at their double bonds. This decolorizes the aqueous solution of halogen (bromine or iodine). The extent of addition of the halogen depends on the number of the double bonds. It can be used as a measure of the extent of unsaturation in the fat or oil. It is measured in terms of a parameter called **iodine number** which is defined as the weight in grams of iodine that can be taken up by 100 g of fat or oil. Higher the iodine number, greater is the degree of unsaturation present in the fat.

Oils with higher iodine number contain higher degree of unsaturation and are preferred, due to their nutritional value. The iodine number of coconut oil is about 8, while that of butter fat is about 26, compared to 81 for olive oil, 93 for groundnut oil and 145 for safflower oil.

Hydrogenation

When exposed to hydrogen at high pressure and temperature in presence of Nickel Platinum or catalyst, an unsaturated fatty acid accepts the hydrogen at the double bonds and is converted to a saturated fatty acids. This is called **hydrogenation** of oil and can be depicted as the following reaction.

Hydrogenated oil is known as ***Vanaspati*** in India



Unsaturated Fatty Acid — Saturated Fatty Acid

Hydrogenation produces oil with mouth feel, stability, melting point and lubricating qualities necessary to meet the needs of many manufacturers. The process of hydrogenation of oils is sometimes referred to as **hardening** of oils. The extent of hydrogenation can be controlled so as to obtain fats of desirable physical consistency. The fat obtained on hydrogenation is neutral in flavour with smoking temperature to make it useful for frying and have good shortening power.

Rancidity

When oils and fats are stored, they undergo changes in their flavour and odour. The fat is said to have become deteriorated and the phenomenon is called **rancidity**. The chemical process involved is called auto-oxidation because the rate of oxidation increases as the reaction proceeds. It is a consequence of two types of chemical reactions viz., hydrolysis and oxidation. Accordingly there are two types of rancidities viz., hydrolytic and oxidative rancidity.

Deterioration of fat due to hydrolysis is of concern primarily in dairy products. It is termed as 'hydrolytic rancidity'. The odour and flavour deterioration is because we taste individual fatty acids obtained from hydrolysis more than the triglyerides themselves. The naturally present lipases in dairy products hydrolyze the fats to give short chain fatty acids like butyric acid which are particularly perceived by the tongue sensory buds.

As hydrolytic rancidity occurs naturally, it is advised to keep butter in the refrigerator.

Under warm and moist conditions, the ester linkages of the fats get hydrolyzed and the fatty acids so obtained undergo oxidation leading to oxidative rancidity. The unsaturated fatty acids are more susceptible to oxidation. In oxidation, initially, peroxides are formed, which in turn, breakdown to hydrocarbons, ketones, aldehydes and smaller amounts of epoxides and alcohols (Sec 8.6). **Peroxide value** of fats measures the extent of rancidity development. It is calculated by the amount of iodine released from potassium iodide by the peroxides.

Another measure of the extent of rancidity is called **acid value** as it measures the free fatty acids formed during decomposition of oil glycerides. It is defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids present in one gram of fat. The acid value is determined by directly titrating the oil-fat in an alcoholic medium against standard potassium hydroxide-sodium hydroxide solution. The value is a measure of the amount of fatty acids which have been liberated by hydrolysis from the glycerides due to the action of moisture, temperature and-or the enzyme lipase. The acid value is also expressed as percent of free fatty acids calculated as oleic acid.

Rancidity is a major concern in food industry. Its chemistry is dealt in detail in the next section. Before proceeding answer the following question.

Check Your Progress Exercise 6

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

1) Tick mark (√) in front of the correct sentences and mark (×) in front of wrong sentences.

i) A large value of saponification number indicates that the fatty acid in the oil has a long hydrocarbon chain.

ii) Iodine number is helpful in detecting unsaturation in fats and oils.

iii) Ground nut oil has more unsaturated fatty acids as compared to olive oil.

iv) The change in flavour and odours of fats and oils on storage is due to enzymatic hydrolysis only.

8.6 DETERIORATIVE CHANGES IN FATS AND OILS AND THEIR PREVENTION

Food processes like heating and frying lead to polymerization of fats that leads to change in molecular weight, colour, viscocity and refractive index of the fat or the oil used. Besides this, it was mentioned earlier that fats and oils get deteriorated due to storage also. The presence of enzymes, atmospheric oxygen and application of high temperature are the factors responsible for such changes. The deteriorative changes in fats and oils are termed rancidity as you have read in the previous subsection: Fats and oils. In some cases containing high convent of PUFA (Linolenic acid) lose the flavour giving a taste to it. This is called **flavour reversion**. It is of great economic concern to the food industry because it leads to the development of various off-flavours and off-odours in edible oils and fat-containing foods, which render these foods less acceptable.

Lipid oxidation is one of the major causes of food spoilage. 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. Let us learn the chemistry of the process of deterioration of fats.

8.6.1 Auto-oxidation, Lypolysis and Thermal Decomposition

Oxidation via a self-catalytic mechanism is the main reaction which takes place in oil becoming rancid. This is called the *oxidative deterioration* of lipids or '**auto-oxidation**'. The auto-oxidation follows a free radical mechanism and can be visualised to be consisting of three stages as follows.

a) Initiation

In the first step of auto-oxidation process called initiation, hydrogen is removed from the fatty acid chain to yield a free radical. The reaction can be shown as below.

$$RH \longrightarrow R^{\bullet} + H^{\bullet} \quad \text{(R and H are free radicals)}$$

b) Propagation

Once a free radical is formed, it combines with oxygen to form a peroxy free radical which can remove hydrogen from another unsaturated molecule yielding a peroxide and a new free radical. This is called '*propagation reaction*' and may repeat up to several thousand times in a kind of chain reaction

$$R^{\bullet} + O_2 \longrightarrow RO_2^{\bullet}$$
$$RO_2^{\bullet} + RH \longrightarrow \underset{\text{(peroxide)}}{ROOH} + R^{\bullet}$$

c) Termination

The propagating chain reactions are terminated through a reaction between the free radicals to yield non-active products:

$$R^{\bullet} + R^{\bullet} \longrightarrow R-R$$
$$R^{\bullet} + RO_2 \longrightarrow RO_2R$$
$$nRO_2 \longrightarrow (RO_2)_n$$

Lipolysis: Rancidity in presence of enzymes, heat and moisture causes the hydrolysis of ester bonds in lipids. This is called **lipolysis.** These resulting peroxides then breakdown to yields low molecular weight aldehydes and ketones which vaporize to give the peculiar off flavour. The flavour threshold for these is as low as 1ppb. Lipolysis occurs during deep fat frying due to large amount of water released from the food and the high temperature. Release of short chain fatty acids by hydrolysis is responsible for the development of an undesirable rancid flavour in raw milk. This is called **hydrolytic rancidity.** However, controlled and selective lipolysis is used in the manufacture of food items as yogurt and bread.

Thermal Decomposition leading to fat deterioration is a result of high temperature heating of fats in the presence of oxygen. This deterioration is due to the oxidative reactions of saturated and unsaturated fatty acids and interaction of nutrients among themselves. The compounds formed are cyclic and ayclic dimers, long chain alkanes, aldehydes, ketones etc.

As a consequence of these reactions, the oil not only loses its flavour and taste but also becomes nutritionally less valuable. Let us learn how this deterioration can be prevented.

8.6.2 Antioxidants

Antioxidants are the substances that can delay the onset or slow the rate of oxidation of auto-oxidizable materials. By virtue of this property the presence of antioxidants provides protection against oxidative changes in fats and oils. These act by reacting with the fatty acid free radical or with the peroxy free radical and thereby terminate the propagation of deteriorative chain reactions. Literally hundreds of compounds, both natural (including vitamins C and E, vitamin A, selenium – a mineral and a group know as the carotenoids) and synthetic, have been reported to possess antioxidant properties. 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.

Some commonly used/present antioxidants in fats and oils and their characteristic are given below:

- **Tocopherols**: These are the most widely distributed antioxidants in nature and 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 odour that may become noticeable if the oil is subjected to high heat.
- **Tertiary butyl hydroquinone** (TBHQ): TBHQ is moderately soluble in oil and slightly soluble in water.
- **Butylated hydroxytoluene (**BHT**)** is an important antioxidant that improves oxidative stability.

Check Your Progress Exercise 7

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

1) List the factors causing deteriorative changes in fats and oils on storage.

   i) ……………….
   ii) ……………….
   iii) ……………….
   iv) ……………….

8.7 APPLICATIONS IN FOODS AND NUTRITION

Lipids play important role in food. They influence the texture, flavour and aroma of foods. The short chain fatty acids obtained as breakdown products of lipids are responsible for the flavour in butter, milk and cheese. You know that due to immiscibility of fats in water, the former separate out from an aqueous medium on standing i.e. form two layers. Therefore, to retain the fat in aqueous medium these need to be emulsified. In food processes, monoglycerides, phospholipids and a wide range of synthetic compounds are used as emulsifiers. Thus, the texture of foods can be influenced by a mixture of fat blends and appropriate emulsifiers.

Fats and oils are extensively used in cookery as a cooking medium, shortening and as seasoning. Since fat and oils have a high boiling point as compared to water, the foods get cooked faster in fat than in water. In many preparations such as cakes, biscuits, chakali and chirote, fats or oils are added to improve the texture. The fat covers the surface of the flour particles and prevents the sticking of particles together.

Shortening is a fat like butter and lard used to make cake or pastry light or flaky.

Carnauba wax is used as glazes for candies, gums, fruit coatings etc. The wax from rice bran is used as a constituent of chocolate enrobes various fruits and vegetable coatings.

From nutrition point of view the fats and other lipids in the diet are important for their energy value. You know that fats have calorie content of approximately 9 kcal per gram which is high as compared to other foods. A high fat intake is said to be responsible for a rise in blood cholesterol level as is indicated by a number of studies. It is, therefore, advised to substitute oils with unsaturated fatty acids for the ones with hydrogenated fats or the fats with saturated fatty acids.

Lipids are considered to have a role in the satiety value of food i.e. the feeling of satisfaction on consumption of food. The essential fatty acids are added to the diet through intake of foods containing fats and oils. Fats act as solvents for fat soluble vitamins which are vitamin A, D, E and K. The vitamins as you know and will read later are very important for health.

Some dietary fats have some harmful effects also. For example, some cyclic fatty acids inhibit the desaturation of stearic acid to oleic acid. This alters membrane permeability and leads to some diseases. Some of the peroxidized products of polyunsaturated fatty acids could also be toxic.

8.7.1 Adulteration of Fats and Oils

You have read that storage and processing causes deterioration of fats and oils. These deteriorative changes are generally not intentional, however the quality of oil gets affected due to this. Maintenance of quality of any food product is of utmost importance keeping in mind the health effects. Efforts are being made at the national level to maintain standards and quality of foods.

When talking of quality we know that there are malpractices which are followed in tampering with the original food to make monetary gains. Oil is no exception to this malpractice of adulteration. Cheap oils and inedible oils are mixed in edible oils for this purpose. You might be familiar with the adulteration of mustard oil with argemone oil obtained from argemone seeds grown widely in our country. Argemone oil is not only mixed in mustard oil but also in coconut, sesame and ground nut oils. This oil is highly poisonous and causes a disease named dropsy in human beings. Another chemical, orthotricresyl phosphate is also used for adulteration of oils as it is insoluble in water but soluble in oils. This adulterant is a cause of permanent damage to nervous system. Some other common adulterants include petroleum products, animal fats in vanaspati and vanaspati in ghee. The **Indian Prevention of Food Adulteration Act** takes care of the adulterations and their preventions in all food products.

8.8 LET US SUM UP

Lipids belong to a class of biomolecules that are rich in energy and give taste and flavour to foods. They occur in nature in almost all plants and animal tissues in the form of oil, waxes, steroids, hormones etc. Some of the plant seeds are rich sources of fats and oils which are the most familiar types of lipids.

Lipids are classified into simple, complex and derived types depending on the structure and nature of groups attached to the basic moieties i.e. fatty acids and glycerol. Fats, oils and waxes are the common types of simple lipids. Fats are solid in state while oils generally obtained from plant sources are liquids. Complex lipids contain a phosphate or a carbohydrate moiety and also the proteins along with lipids are important constituents of cell membrane. Derived lipids are all those types that are obtained as hydrolytic products of other types.

Chemically lipids are formed by the esterification of fatty acids and glycerol. Therefore they are also called as glycerides. Replacement of all the –OH groups of glycerol gives triglycerides. The triglycerides may have saturated or unsaturated fatty acids in them. The triglycerides with saturated fatty acids are generally solids of room temperature and called the fats. The ones with unsaturated fatty acids are called the oils.

Physical characteristics of fats and oils include their low densities as compared to water, immiscibility in water and not very sharp melting point. The chemical reactions of fats and oils are in some way helpful in identifying the nature of fatty acids and glycerol moiety in them. Some of these chemical reactions are saponification, halogenations, oxidation on storage etc. The last property of fats and oils is very important to food scientists and food industry. This is defined by the rancidity of fats and oils. Rancidity is actually the deterioration of fats and oils which takes place due to their oxidation and hydrolysis on storage and food processing. The factors responsible for this deterioration are oxygen, heat, moisture and also the enzymes.

Lipids are very important in food industry. These are used to enhance aroma, flavour and taste to many foods during processing. They are good tenderizers and emulsifiers, and find use in baked foods. Lipids have a lot of nutritional value. They are high energy providing components of food and very important sources of fat soluble vitamins. However, excessive use of saturated fats causes adverse effects on health, especially in raising the cholesterol levels. Therefore a judicious use of fats and oils in diet is recommended.

8.9 KEY WORDS

Antioxidant : Any substance that reduces oxidative damage by scavenging free electrons. Antioxidants terminate these chain reactions by removing free radical intermediates, and inhibit other oxidation reactions by being oxidized themselves. As a result, antioxidants are often reducing agents such as thiols or polyphenols.

Emulsion : A dispersion of one liquid in a second immiscible liquid. Since the majority of emulsions contain water as one of the phases, it is customary to classify emulsions into two types: the oil-in-water (O/W) type consisting of droplets of oil dispersed in water, and the water-in-oil (W/O) type in which the phases are reversed. The continuous liquid is referred to as the dispersion medium, and the liquid which is in the form of droplets is called the disperse phase.

Essential fatty acid : An unsaturated fatty acid, such as linoleic acid, that is required for normal, healthy functioning of the body. These are therefore dietary essentials: linoleic (C18: 2 ω6) and α-linolenic (C18: 3 ω3).

Hydrogenation : Hydrogenation is a reductive chemical reaction which results in an addition of hydrogen (H_2) usually to saturate organic compounds. The process constitutes the addition of hydrogen atoms to the double bonds of a molecule through the use of a catalyst. Lipids are hydrogenated to achieve increased plasticity (stiffness) of the liquid oils at room temperature.

Peroxide value : The Peroxide value of an oil or fat is used as a measurement of the extent to which rancidity reactions have occurred during storage. Other methods are available but peroxide value is the most widely used. The peroxide value is defined as the amount of peroxide oxygen per 1 kilogram of fat or oil.

Rancidity : Decomposition of fats, oils and other lipids by hydrolysis or oxidation, or both. Hydrolysis will split fatty acid chains away from the glycerol backbone in glycerides. These free fatty acids can then undergo further auto-oxidation. Oxidation primarily occurs with unsaturated fats by a free radical-mediated process. These chemical processes can generate highly reactive molecules in rancid foods and oils, which are responsible for producing unpleasant and noxious odors and flavours.

PUFA : Polyunsaturated fatty acid, an unsaturated fatty acid whose carbon chain has more than one double or triple valence bond per molecule; found chiefly in fish and corn and soybean oil and safflower oil.

Saponification : The hydrolysis of an ester under basic conditions to form an alcohol and the salt of a carboxylic acid. Saponification is commonly used to refer to the reaction of a metallic alkali (base) with a fat or oil to form soap.

Trans-fats : Trans fat is the common name for a type of unsaturated fat with trans isomer fatty acid(s). Trans fats may be monounsaturated or polyunsaturated. Most trans fats consumed today are industrially created by partially hydrogenating plant oils.

Triglycerides : Triglycerides have a three-carbon backbone (glycerol) to which are attached fatty acids, which are strings of carbon and hydrogen atoms.

Waxes : Any of various natural, oily or greasy heat-sensitive substances, consisting of hydrocarbons or esters of fatty acids that are insoluble in water but soluble in nonpolar organic solvents.

8.10 TERMINAL QUESTIONS

1) Name two lipid sources each from the category of cereals, pulses, seeds and animals.
2) What is the basis of lipid classification? Name the various types.
3) List the physical and the chemical differences between fats and oils?
4) What are emulsions? Give example of a naturally occurring emulsion.
5) What does a high saponification number and a high iodine value of a fat indicate?
6) What are the advantages and disadvantages of hydrogenation of oils?
7) Define rancidity and name the type of chemical reactions involved.
8) Write short note on the nutritional applications of lipids.

8.11 ANSWERS CHECK YOUR PROGRESS

Check Your Progress Exercise 1

1) Amaranth > cow milk >egg > sardine fish> soybean >almonds

Check Your Progress Exercise 2

1) i) fatty acids, glycerol.
   ii) triglycerides
   iii) simple
   iv) derived
   v) glycolipids

Check Your Progress Exercise 3

1) (ii)

Check Your Progress Exercise 4

1) (iii)

Check Your Progress Exercise 5

1) a) ---iii)
   b) ---i)
   c) ---iv)
   d) ---ii)

Check Your Progress Exercise 6

1) i) (×) ii) (√) iii) (√) iv) (×)

Check Your Progress Exercise 7

1) i) oxygen
   ii) heat/temperature
   iii) moisture
   iv) enzymes

8.12 ANSWERS TO TERMINAL QUESTIONS

1) Cereals – wheat, rice
   Pulses -- black gram, pea
   Seeds – mustard, sunflower
   Animals – fish, pig
2) Lipids are classified on the basis of their chemical composition. The three classes are:
   Simple lipids – constituted of fatty acids and glycerol.
   Complex lipids – Besides fatty acids and glycerol they have phosphate carbohydrate and proteins as constituents.
   Derived lipids – these are the hydrolysis products of the other types.
3) Fats are solids at room temperature while oils are liquids. Chemically the former contain fatty acids with saturated hydrocarbon chain while the latter contain fatty acids which have unsaturation in their hydrogenous chain
4) Emulsions are heterogenous systems obtained by mixing two immiscible liquids. One of the liquid acts as a continuous phase on which the other liquid called a discontinuous phase is dispersed. Milk is an example of a naturally occurring emulsion.
5) A high saponification number indicates a small chain fatty and while a high value of iodine number indicates high unsaturation in fatty acid.
6) Hydrogenation of oils leads to saturation of fatty acids present in it. This gives consistency to the oil. On the other hand hydrogenated oils are not good from health point of view as these increased the cholesterol level in blood.
7) Rancidity is deterioration of fats and oils on storage and heating. The chemical reactions involved mainly are oxidation and hydrolysis.
8) Refer to subsec. 8.4.1 and Sec 8.7.

8.13 SOME USEFUL BOOKS

Bennion Marion (1980). The Science of Food, Wiley John and Sons

Manay N. Shakuntala and M. Shadaksharaswamy (1987). Foods: Facts And Principles Wiley eastern Ltd.

Mudambi R. Sumati and Rao Shalini (1985). Food science, Wiley E

Govt. of Indian manual (2005) Analysis of foods-Fats and oils

Meyer, L.H. (1969). Food Chemistry Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne.