UNIT 4 LIPIDS

Structures

4.0 OBJECTIVES

After reading this unit, you will be able to:

- explain lipids, their importance and functions;
- describe different types of lipids;
- identify food items rich in lipids; and
- explain lipid associated disorders.

4.1 INTRODUCTION

Lipids are chemically a distinct group of substances, which are water insoluble. Fats, oils and other greasy compounds that are part of our diet are included in lipids. The commonly used term for lipids is fat. Like carbohydrates and proteins, lipids also contain carbon, hydrogen and oxygen. However, the ratio (77: 12: 11 approximately) differs. In addition to carbohydrates, lipids are the other basic fuel source and are highly concentrated (9.2 Kcal/gm) and give about twice the energy value of carbohydrates. Some food items are extremely rich in lipids. Lipids perform various functions in the body. Primarily it acts as a stored form of energy besides being important component of cell membranes. There are many health disorders associated with lipids.

4.2 IMPORTANCE AND FUNCTIONS

Some of the food items that are identified as lipids are oils, butter etc. Food items rich in lipids are eggs, meat, nuts and seeds. We need fat in diet to keep our body healthy and to perform body, vital functions.

4.2.1 Utility of Lipids in Biological System

Energy: A major function of fat is to supply an efficient fuel to all tissues except central nervous system and brain, which depends on glucose.

Thermal insulation: The body fat underneath the skin regulates/controls body temperature.

Vital organ protection: A web-like padding of adipose fat surrounds many vital organs such as kidney, protecting them from mechanical shock and providing a supporting structure.

Nerve impulse transmission: Fat layer surrounding nerve fibers provide electrical insulation and transmit nerve impulses.

Tissue membrane structure: Major constituent of cell membrane structure, which is vital for transport of molecules across membrane.

Cell metabolism: Complexes of fat and protein called lipoproteins carry fat in the blood to all cells.

As precursor substances: Fatty acids and cholesterol are precursor for many important molecules involved in metabolic functions and tissue maintenance.

Emulsifier: Amphipathic lipids such as phosphoglycerides, bile acids act as emulsifiers in our body.

Hormonal and Vitaminogenic: Many of the hormones (sex hormones) and vitamins are of fatty nature. Synthesis of these hormones requires lipids.

4.2.2 Industrial Use of Lipids

Lubrication: Almost all machinery requires lubrication for which lipids is needed.

Cosmetics: Lipids are extensively used in this industry. Volatile lipids are used in perfumes, deodorant, soap etc.

Food flavour: Lipids in food is responsible for flavour and other attributes like juiciness, texture etc. You will learn more about this in other units.

Pharmaceuticals: Many of the drugs have lipid base given orally, through injection and applied topically, like synthetic hormones, steroids, ointment and lotion.

Absorbents: Lipids are used to absorb / adsorb colour also. For a better shining, we use polish on our shoes or any other articles, which has lipid base.

4.2.3 Miscellaneous

In addition to their role as energy source/reservoir and as the components of membranes, lipids derivatives do perform some other vital functions *Phosphatidylinositol* and its phosphorylated derivatives act as intracellular signals to regulate cell structure and metabolism.

Eicosanoids are paracrine hormones, substances that act only on cells near the point of synthesis. Eicosanoids are derived from arachidonic acid, a 20-carbon polyunsaturated fatty acid. There are three classes of eicosanoids: (a) Prostaglandins: They were first isolated from prostrate gland. They act on tissues by regulating intracellular messenger, cyclic AMP. Different prostaglandins perform different functions such as smooth muscle contraction, regulation of blood flow and rise of body temperature causing pain and inflammation. (b) Thromboxanes: Produced by platelets and facilitates clot formation. (c) Leukotrienes: These are observed in white blood cells and linning of the airway to the lungs. These induce muscle contraction. Overproduction of leukotrienes is responsible for asthamatic attacks.

Role of Eicosanoids in human

- Cardiac function
- Regulation of blood pressure
- Bronchial muscle contraction
- Role in inflammation
- Vascular contraction
- Platelet aggregation
- Gastric secretion
- Intestinal motility
- Renin release, sodium excretion
- Lipolysis
- Luteolysis,
- Uterine contraction.

Check Your Progress 1

1) Name three food items rich in lipids.

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2) How much kilocalories are generated from a gram of fat?

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3) Name any three functions of body fat.

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4) What are the industrial applications of lipids?

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5) Eicosanoids are ..... hormone, which are derived from ..... acid.

4.3 CLASSIFICATION

Lipids are not a polymer of repeating nonnumeric unit similar to polysaccharide or protein. Lipids are compound soluble in ether or benzene or in chloroform but only sparingly soluble in water. There are several basis of lipid classification such as their hydrolysis product.

4.3.1 Classification on the Basis of Chemical Nature

On the basis of chemical nature lipids are classified into four types.

i) **Simple lipids:** These are esters of fatty acids with various alcohol. Examples: Fats, oil and waxes.

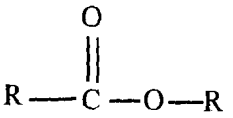

Fig. 4.1: Structure Ester

ii) **Compound lipids:** These are esters of fatty acids containing groups in addition to an alcohol and fatty acids. Examples: Phospholipids, Glycolipids, Lipoproteins.

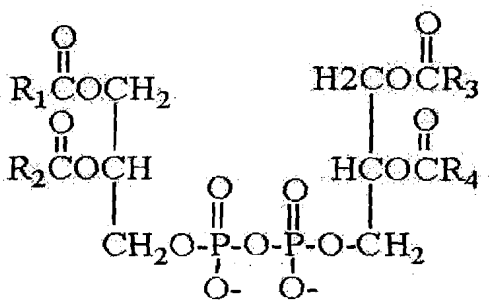

Fig. 4.2: General structure of a compound lipid

iii) **Derived lipids:** These are derived from above mentioned phospholipids, glycolipids etc.

iv) **Miscellaneous:** It includes Sterol, Tapenes etc.

Another classification of fatty acids are: **Essential fatty acids** and **Non-essential fatty acids.** Non-essential fatty acids are those which body can synthesize itself or their inclusion in diet is not necessary whereas, essential fatty acids are those which have to be obligatorily included in diets and are able to cure the diseases caused by the diet deprived of essential fatty acids. The number of essential fatty acids are three. They are Linoleic, Linolenic and Arachidonic acid. The linoleic can be converted to linolenic and arachidonic acids and therefore, the presence of linoleic acid in diet can manage other two essential fatty acid.

4.3.2 Classification on the basis of Saponification

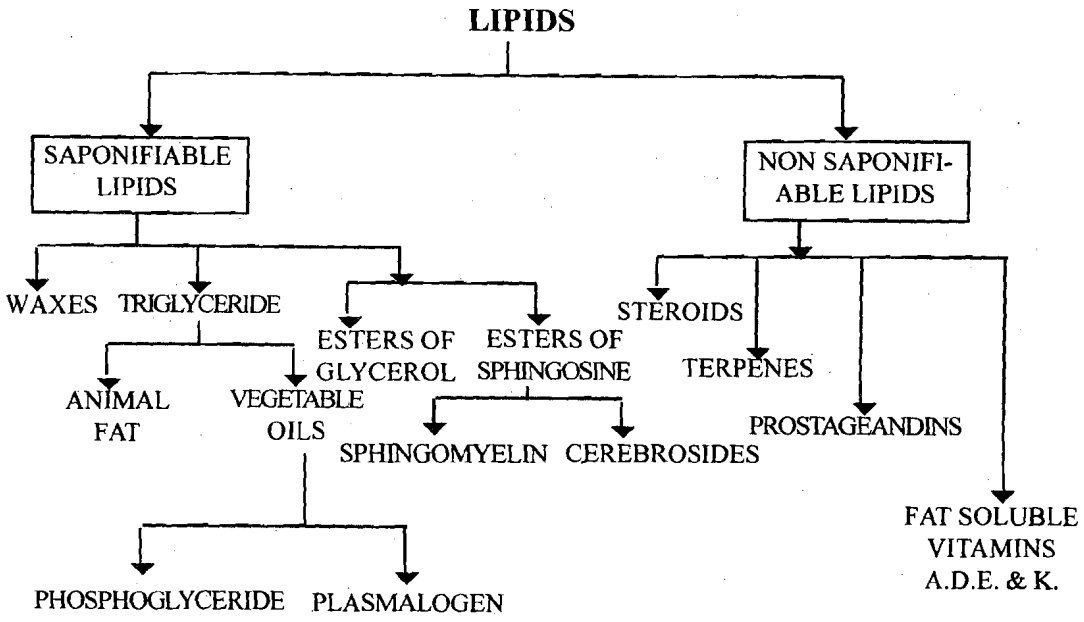

Fig. 4.3: Classification of lipids on the basis of Saponification

Check Your Progress 2

1) What are simple lipids? Give any two examples of the same.

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2) Name three essential fatty acids.

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3) On the basis of chemical, lipids are classified mainly as .....

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4) Give some examples of compound lipids.

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4.4 LIPIDS OF BIOLOGICAL IMPORTANCE

4.4.1 Fatty Acids

These are the building blocks of most lipids. They are long chain organic acids having 4 to 24 carbon atoms. They have a single carboxyl (COOH) group and a long non-polar hydrocarbon tail, which makes it non-polar (water insoluble)

and greasy in nature. Fatty acids do not occur in free form in cells but are bound tightly in different types of other lipids. Fatty acids are of many types. They vary in chain length and also differ in the presence, number and positions of their double bonds (*Table 4.1*). Saturated fatty acids are those that do not possess any double bonds in hydrocarbon tail. Their general formula is CH_3-$(CH_2)_n$-COOH. Unsaturated fatty acids on the other hand have one or more double bonds. Natural fatty acids have even number of carbon atoms.

Table 4.1: Some naturally occurring fatty acids

Carbon atoms	Common Name	Nature
12	Lauric acid	Saturated (no double bond)
14	Myristic acid	Saturated
16	Palmitic acid	Saturated
18	Stearic acid	Saturated
	Oleic acid	Unsaturated, one double bond;C9=10
	Linoleic acid	Unsaturated, two double bonds; C6=7, 9=10
	Linolenic acid	Unsaturated, three double bonds; C3=4, 6=7,9=10
20	Arachidic acid	Saturated
	Arachidonic acid	Unsaturated, four double bonds; C6=7, 9=10, 12=13, 15=16
24	Lignocenic acid	Saturated

4.4.2 Triglycerides

These are fatty acid esters of glycerol and are most abundant lipids, also often referred as fats. Oils also come in the same category but the only difference in fat and oil is that, at room temperature fat is solid whereas oil is liquid. More or less all animal lipid is fat. A *triglyceride* has a glycerol with three fatty acids attached to it. Triglycerides act as storage fat in plant and animal cells. In eukaryotic cells, triglycerides form microscopic droplets, which act as energy storehouse. Specialized cells called adipocytes or fat cells store large amounts of triglycerides that almost occupy the cell interior. Why triglycerides are preferred as storage fuel rather than carbohydrates such as starch or glycogen? There are two reasons for this: first, being hydrophobic, triglycerides do not carry extra weight of water which carbohydrates, being hydrophilic, do carry and are not advantageous to the cell. Second, carbon atoms of triglycerides are more reduced (more hydrogen atoms attached) than the carbon atoms of sugars and this gives twice the amount of energy per gram on oxidation than carbohydrates. Triglycerides stored under the skin also serve as an insulator against low temperatures. Seals, walruses, penguins and many other warm-blooded animals are well padded with triglycerides. In hibernating animals, triglyceride serves both as an energy source as well as an insulator.

Fatty acids attached in triglycerides could be same or different. Triglycerides with unsaturated fatty acids are liquid at room temperature. Such triglycerides are converted into solid fat by adding hydrogen to the double bond of their fatty acids. This process is used in the manufacturing of hydrogenated fats commonly called as "DALDA". Oxidation (addition of oxygen) of triglycerides by air results in rancid fat, which is off-taste and has awful smell. In body, vitamin E, vitamin C and other reducing substances prevent oxidation of fat.

4.4.3 Waxes

These are fatty acid esters of long chain alcohols with 16 to 22 carbon atoms. Fatty acids in waxes may be saturated or unsaturated and contain 14 to 36 carbon atoms. Skin, hair, wool and fur have waxes, which serve as a protective covering and are secreted by skin glands. Waxes are the chief storage form of metabolic fuel in plankton, a free-floating marine microorganism. Waxes also have pharmaceutical and other uses in industries such as ointments, lotions and polishes.

4.4.4 Phospholipids

Biological membranes are rich in phospholipids. They have a highly polar (water loving) "head" group and a hydrophobic (water repelling) hydrocarbon tail. These characteristics favour formation of biological membranes in a double/ bilayer structure with semi-permeable property. As the name implies, these lipids contain phosphorous and are structural components of biological membranes. A phospholipid contains a glycerol with two fatty acids attached to carbon one, two and a phosphate bounded to third carbon in the form of phosphoric acid to which a second alcohol is attached. Different phospholipids differ in their head group alcohol. Within the same phospholipid class, say phosphatidylcholine (a choline containing phospholipid), there may exist a number of molecular species differing in fatty acid composition.

In some phospholipids, one of the fatty acids is attached to glycerol in *ether,* rather than *ester* linkage. These lipids are called plasmalogens and are present in vertebrate heart tissue and constitute about half of the phospholipid content. Plasmalogens are also present in the membrane of certain bacteria and some invertebrates. The function of plasmalogens is not precisely known. *Platelet activating factor*, a type of plasmalogen, released by basophils (a type of white blood cells) plays an important role in inflammation and allergic response.

4.4.5 Sphingolipids

These are present in membranes. They do not contain glycerol but possess a long-chain fatty acid and one long-chain amino alcohol called *sphingosine* and a polar alcohol. The three carbons of sphingosine are structurally analogous to the three carbons of glycerol found in phospholipids. Nervous system is rich in sphingolipids. There are three types of sphingolipids differing in polar head groups: (a) Sphingomyelins: They contain phosphorylcholine or phosphorylethanolamine as the head group and are clubbed with phospholipids. (b) Glycosphingolipids: As the name indicates they contain one or more sugars as head group. (c) Gangliosides: It contains complex sugars.

4.4.6 Sterols

They contain no fatty acids and are important component of membranes. They consist of four fused rings, three with six carbons and one with five. Cholesterol is the major sterol in animal tissues and has a polar hydroxyl group. Sterols serve as precursor for many compounds, for example, steroid hormones, which regulates gene expression; bile acids that facilitates fat digestion in the intestine.

Check Your Progress 3

1) Which is the most abundant lipid? Write the function of this lipid.

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2) Name the major sterol of animal tissues.

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4.5 LIPID DISORDERS

Lipids are required in the body for different structural and functional activities. A dietary lipid deficiency may alter/affect these functions to varying extent.

4.5.1 Hypovitaminosis

Lipids are essential for the absorption of fat-soluble vitamins, which may get affected in absence of sufficient fat.

4.5.2 Ketosis

A special condition occurs in the body when the liver catabolizes excessive amounts of fatty acids in the absence or scarcity of carbohydrates. This condition is called "ketosis" and is observed:

- When glycogen stores are depleted, stored body fats becomes the chief energy source as in case of starvation
- When high fat and low carbohydrate diet is consumed
- In untreated diabetes mellitus.

In ketosis, liver gets flooded with fatty acids coming from diet or stored fat and produces compounds called *ketones*. These compounds cannot be oxidized by the liver and are then put in the blood. As the blood ketone levels go up, they are excreted in the urine. This state/condition is called *ketonuria*. The symptoms of ketosis include greater urine volume than usual, depressed appetite, nausea, excessive tiredness, dizziness, and bad breath. Prolonged elevation of blood ketones (which are acids) is dangerous as it causes the blood to become acidic resulting eventually in death. Ketosis disappears when carbohydrates are consumed and utilized by the body.

4.5.3 Coronary Heart Diseases (CHD)

Excess fat intake relates to the prevalence of diseases such as obesity, heart diseases and cancer. Most people require at least 15 to 20 per cent of the kilocalories as fat to provide a palatable diet with sufficient satiety value. Coronary heart disease refers to damage to the heart muscle due to inadequate blood supply

from the coronary arteries. Fat deposition takes place in the arteries in the form of plaques and this condition is called atherosclerosis. Plaques contain cholesterol, phospholipids, triglycerides, connective tissue and fibrin. Formation of plaques narrow the blood vessel lumen through which blood flows. Platelets, a type of blood cells, also adhere to the rough surface of plaques. These changes in the blood vessels decrease blood flow and a condition called myocardial infarction (heart attack) may develop, which could be fatal. Many factors including fat rich diet have been implicated as possible causes of CHD. A diet low in fat is advisable to prevent such disorders.

i) **Dietary fat and cancer:** Dietary fat has been linked to cancer based on epidemiological data. Countries with high fat intake have high death rate due to cancer of colon, breast whereas those with low fat consumption have low incidence of cancer.

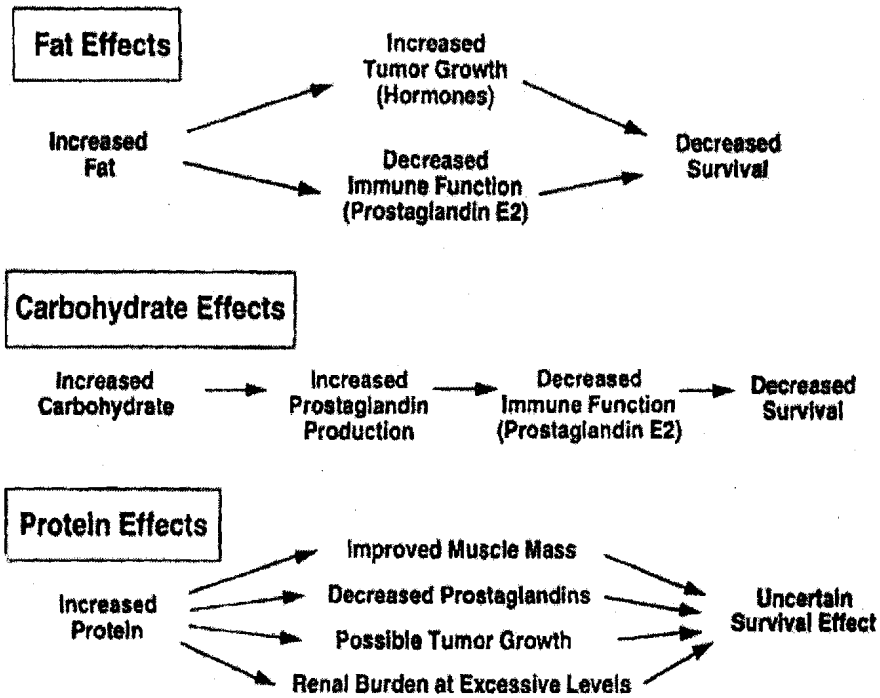

Fig. 4.4: Effects of higher intake of dietary Fat, Carbohydrates and Proteins

ii) **Nicemenn-Pick disease:** There are some inherited lipid disorders that needs attention. There is a balance between lipid synthesis and breakdown. The breakdown is initiated by hydrolytic enzymes in the lysosomes (an organelle inside the cell). When breakdown of sphingolipid is altered due to a defect in hydrolytic enzyme, partial breakdown products of this lipid accumulate in the tissues. In Niemann-Pick disease, sphingomyelin accumulates in brain, spleen and liver causing mental retardation and early death.

iii) **Tay Sachs disease:** In Tay-Sachs disease, ganglioside accumulates in the brain and spleen due to enzyme deficiency. The symptoms of this disease are progressive retardation in development, paralysis, blindness and childhood death. These disorders can now be diagnosed and averted at a very early stage during pregnancy by genetic counselling.

Check Your Progress 4

1) Write the symptoms of ketosis.

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2) What is the blood pH during ketosis?

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4.6 LET US SUM UP

Lipids are water-insoluble greasy substances. Like carbohydrates, they are basic fuel substances and provide twice as much energy. They are important components of biological membranes and lipid derivatives play vital cellular functions. There are diseases associated with lipids particularly coronary heart diseases which could be fatal. Most of the animal lipids are fat and the fatty acids are saturated in nature. The essential amino acids are linoleic, linolenic and arachidonic acid. Lipids are having wide biological as well as industrial application.

4.7 KEY WORDS

Lipids : Compound that is soluble in ether or benzene or in chloroform but only sparingly soluble in water.

Emulsifier : It is the substance or food additives which is used to keep two non-mixing liquids dispersed and in suspension.

Chylomicrons : Lipid-protein complex with outer protein covering is called chylomicrons.

Triglycerides : Lipids with fatty acids attached to glycerol is called triglycerides.

Phospholipid : It is the lipid with a glycerol, two fatty acids, a phosphate and a second alcohol attached.

4.8 SOME USEFUL BOOKS

Lawrie, R.A. (1998). *Meat Science*, (6th edition), Wood head Publishing Ltd., Cambridge, England.

Nelson, D.L. and Cox, M.M. (2000). *Principle of Biochemistry*, Worth Publishers Inc., New York, U.S.A.

Williams. S.R. (1990). *Essentials of nutrition and diet therapy*, Times Mirror, Mosby, College Publishing, St. Louis, Missouri, U.S.A.

Williams, E.R. and Caliendo, M.A. (1984). *Nutrition- Principles, issues and applications*, McGraw-Hill Book Company, New York, U.S.A.

4.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Egg, meat and nuts are three food items rich in lipids.
2) 9.2 Kcal are generated from a gram of fat.
3) Three functions of body fat are — energy source, insulation and precursor for other substances.
4) Lipids are used as, cosmetics, food flavour, absorbent and also in pharmaceuticals and lubrication of machineries
5) Paracrine, Arachidonic acid.

Check Your Progress 2

1) Simple lipids are esters of fatty acids with various alcohol. Examples: Fats, oil and waxes.
2) Linoleic, Linolenic and Arachidonic acid are example of three essential fatty acids.
3) Simple lipids, compound lipids, derived lipids.
4) Phospholipids, glycolipid and lipoproteins.

Check Your Progress 3

1) Triglycerides are the most abundant lipids. The main function of this lipid is to store energy.
2) Cholesterol.

Check Your Progress 4

1) The symptoms of ketosis are as follows:
   - Bad breath
   - Dizziness
   - Nausea
   - Depressed appetite
   - Greater urine volume
2) The blood pH during ketosis is acidic.