Introduction to Food Science and Engineering

Food Constituent: Lipids

Prof. Dr. S M Iqbal Hossain
Dept. of Food Science and Engineering

Lipids

- **Lipids:** (Greek: lipids-fat) are of great importance to the body as the chief concentrated storage form of energy, besides their role in cellular structure and various other biological functions.
- **Definition:** The lipids are a heterogeneous group of organic compounds (including fats, oils, steroids, waxes and related compounds) which are relatively: 1. insoluble in water, and 2. soluble in nonpolar organic solvents like alcohol, ether, chloroform, benzene etc.
- Lipids are not polymeric substances like protein, polysaccharide & nucleic acid, rather they are mostly small molecules. Building blocks of most of the lipids are fatty acid but some lipids such as cholesterol, lack fatty acid.
- The majority of lipids are fats and oils which are derivatives of fatty acids. Other lipids include phospholipid, glycolipid & lipoprotein.

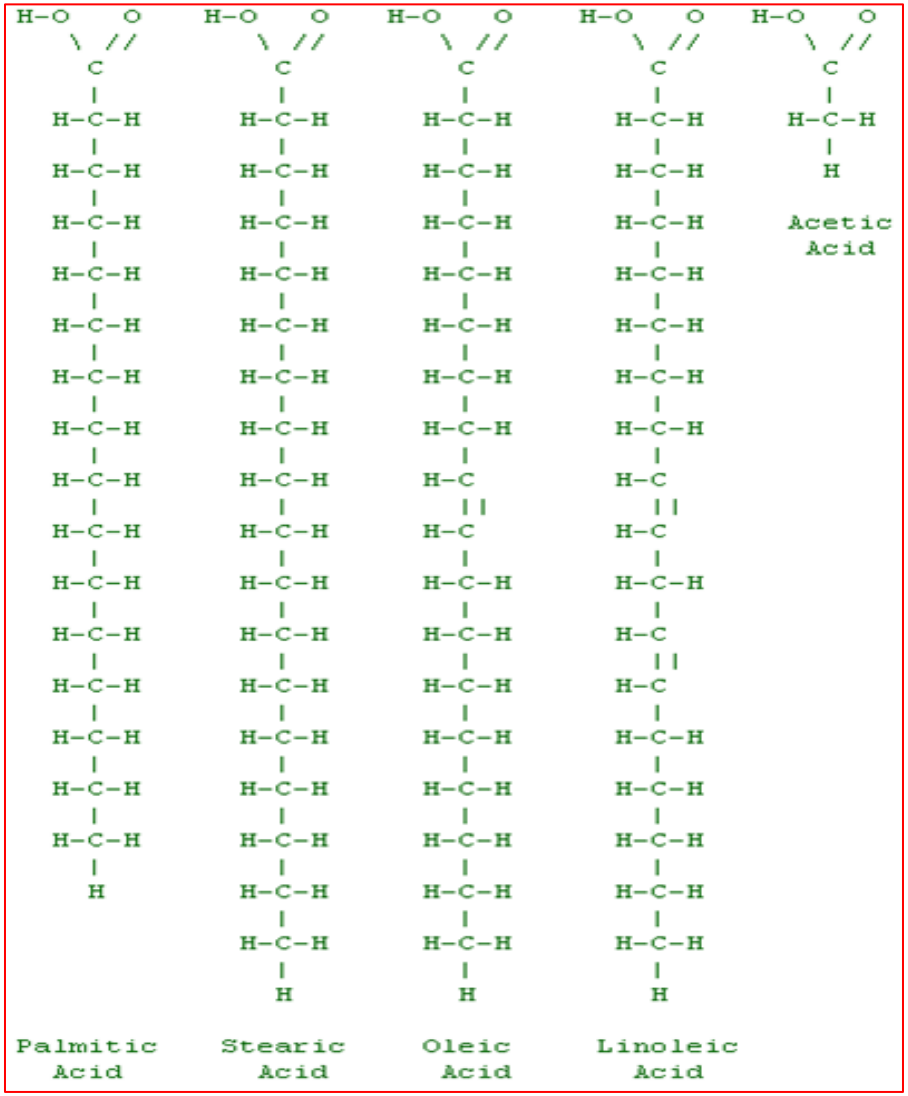
Saturated and Unsaturated Fatty Acid

Fatty Acids: The fatty acids are usually monocarboxylic acids with straight chains containing even number of carbon atoms.

Fatty acids are Saturated or unsaturated. Both saturated and unsaturated fatty acids are the constituents of lipids.

Examples:

1. Palmitic Acid
2. Stearic Acid
3. Oleic Acid
4. Linoleic Acid
5. Acetic Acid



Classification of Lipids

Lipids are broadly classified into 3 classes: Simple, Complex and Derived lipids

1. Simple lipids: Esters of fatty acids with alcohols. These are of two types.

(a) Fats and Oils (triacylglycerols): These are esters of fatty acids with glycerol. The difference between fat and oil is only physical. Thus, oil is a liquid while fat is a solid at room temperature.

(b) Waxes: Esters of fatty acids (usually long chain) with alcohols other than glycerol. These alcohols may be aliphatic or alicyclic. Cetyl alcohol is mostly found in waxes. Cetyl alcohol also known as palmityl alcohol, is a fatty alcohol with the formula $CH_3(CH_2)_{15}OH$. At room temperature, cetyl alcohol takes the form of a waxy white solid or flakes.

2. Complex or compound lipids: These are esters of fatty acids with alcohols containing additional groups such as phosphate, nitrogenous base, carbohydrate, protein etc. Examples are Phospholipids, Glycolipids, Lipoproteins etc.

Classification of Lipids

(a) Phospholipids: They contain phosphoric acid and frequently a nitrogenous base.

(b) Glycolipids: Glycolipids are lipids with a carbohydrate attached by a glycosidic bond. These lipids contain a fatty acid, carbohydrate and nitrogenous base.

(c) Lipoproteins: Macromolecular complexes of lipids with proteins

(d) Other complex lipids: **Sulfolipids** (Lipids which possess a sulfur-containing functional group), **Aminolipids** (lipids based on one or two *amino* acids linked to a fatty acid through an amide bond) and **lipopolysaccharides.**

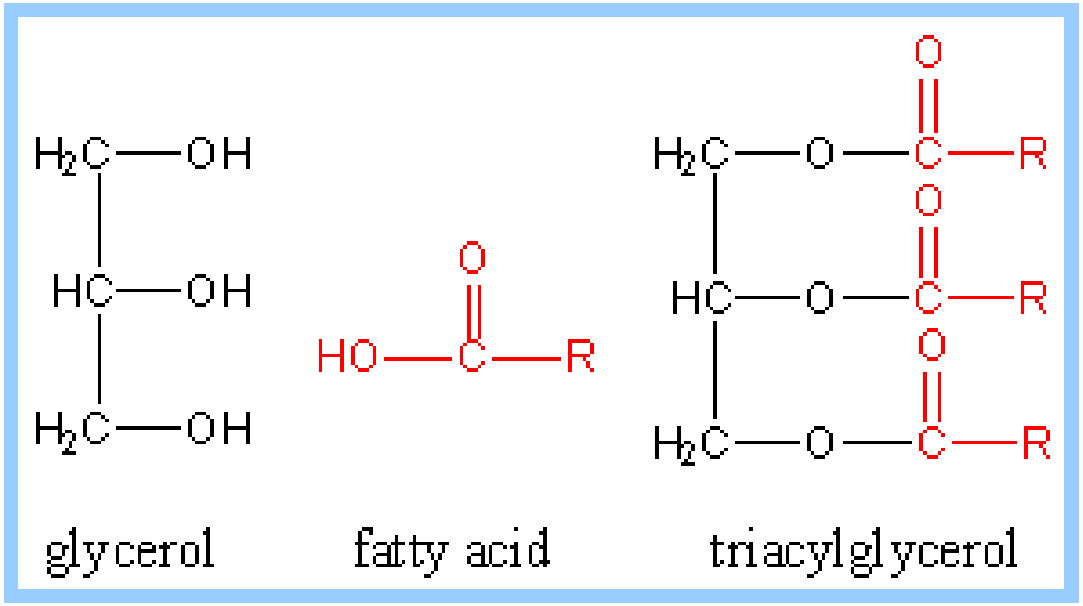
3. Derived lipids: These are derivatives obtained on hydrolysis of group 1 and group 2 lipids which possess the characteristics of lipids. These include glycerol and other alcohols, fatty acids, mono- and diacylglycerols, lipid (fat) soluble vitamins, steroid hormones, hydrocarbons and ketone bodies.

Triacylglycerol

- **Triglyceride** (TG) (also called triacylglycerol (TAG), or triacylglyceride) is an ester derived from glycerol and three fatty acids (*tri-+glyceride*). Triglycerides are the main constituents of body fat in humans and animals, as well as vegetable fat. They are also present in the blood to enable the bidirectional transference of adipose fat (fats in adipose tissue) and blood glucose from the liver, and are a major component of human skin oils.

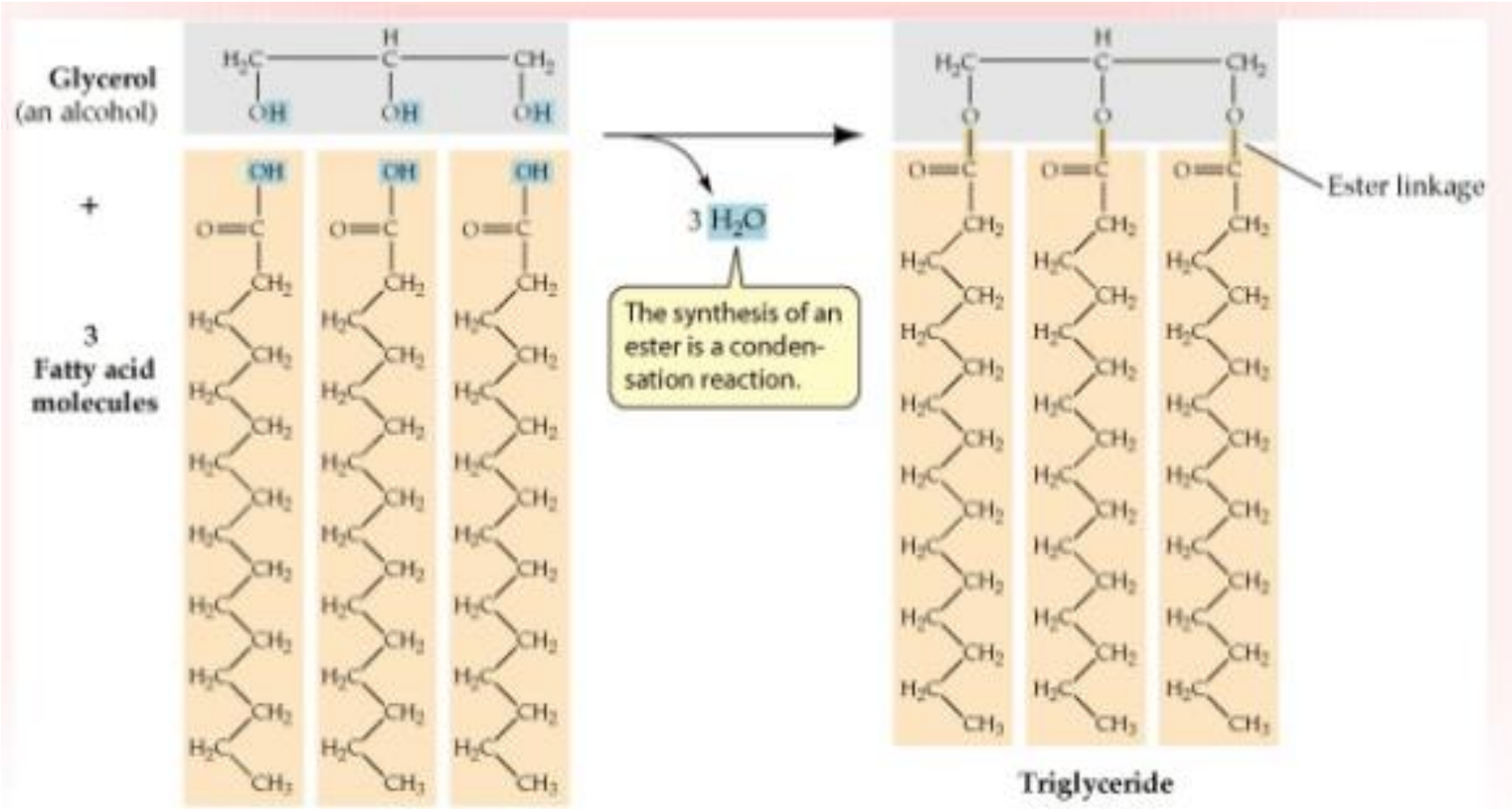
- **Glycerol** (also called glycerine or glycerin) is a simple polyol (an alcohol containing multiple hydroxyl groups) compound. It is a colorless, odorless, viscous liquid that is sweet-tasting and non-toxic. The glycerol backbone is found in all lipids known as triglycerides. It is widely used in the food industry as a sweetener and humectant (a substance that keeps things like food, cosmetic, medicine moist) and in pharmaceutical formulations. Glycerol has three hydroxyl groups that are responsible for its solubility in water and its hygroscopic nature.

Triacylglycerol



Triglycerides: Are fats carried in the blood from the food we eat. Excess calories, alcohol, or sugar in the body are converted into triglycerides and stored in fat cells throughout the body.

Lipids (Triglyceride)

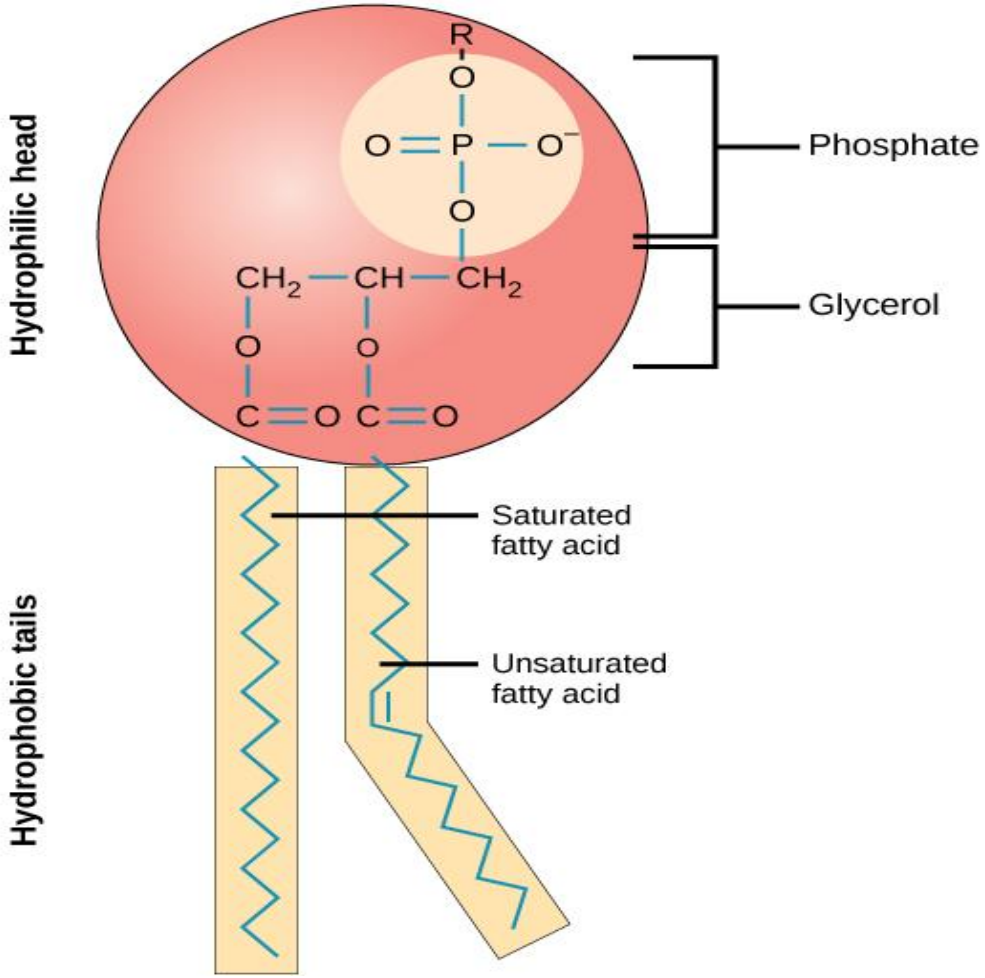


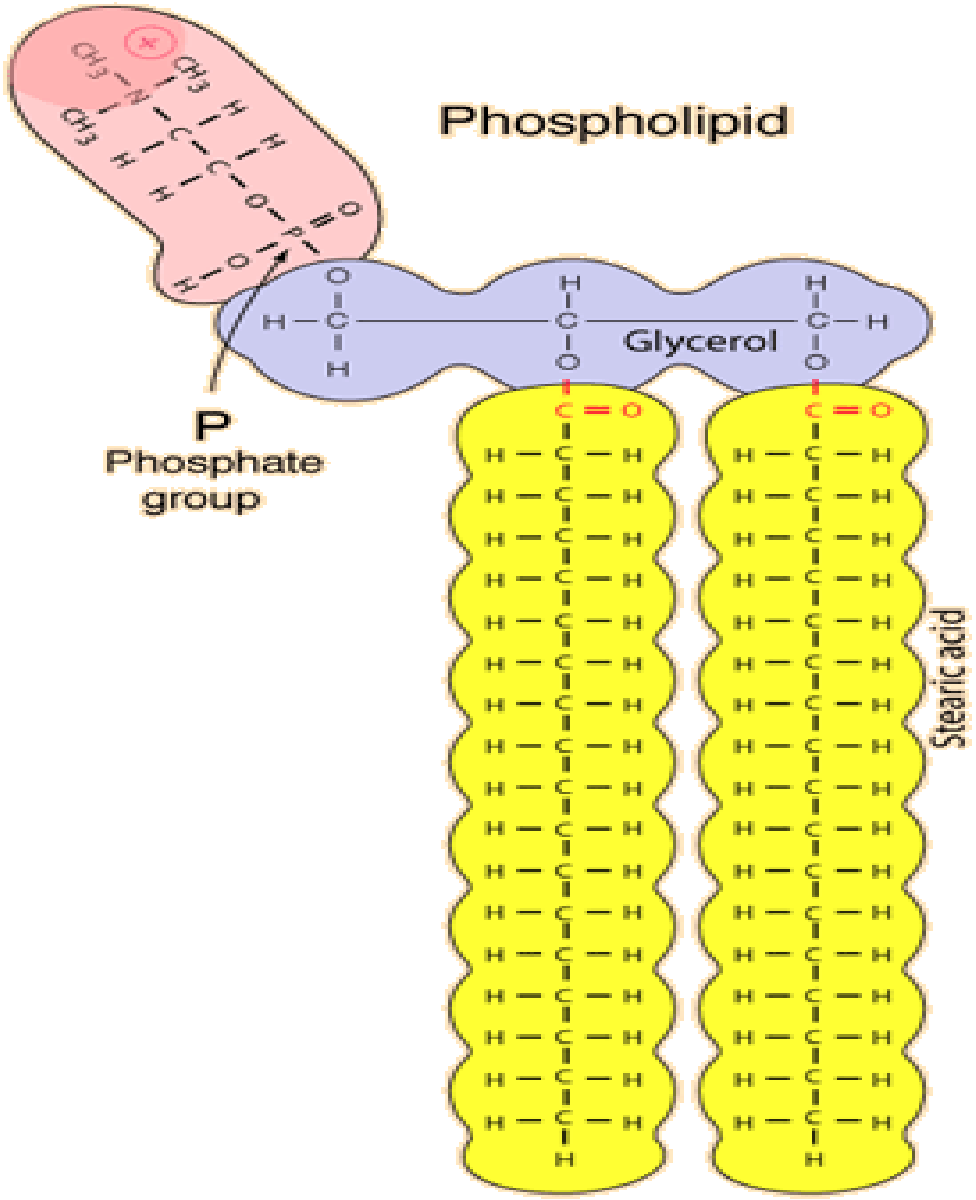
Fats and Oils are triglycerides, composed of three fatty acids covalently bonded to a glycerol molecule by ester linkages.

Phospholipids

- Phospholipids make up an important class of lipids for the construction of cell membranes. The phospholipids are not "true fats" because they have one of the fatty acids replaced by a phosphate group.
- This sketch of a phospholipid molecule shows two fatty acids and a phosphate group attached to a glycerol backbone. Stearic acid is shown as the fatty acid, but there are many variations in the fatty acids.
- Phospholipids tend to arrange themselves into double-layered membranes with the water-soluble phosphate ends on the outside and the fatty acide extensions on the inside.
- "If phospholipid molecules are shaken in a glass of water, the molecules will automatically form double-layered membranes. It is important to understand that the membrane formed is not rigid or stiff but resembles a heavy olive oil in consistency. The component phospholipids are in constant motion as they move with the surrounding water molecules and slide past one another

Structure of a phospholipid Molecule




Phospholipid
Glycerol
P
Phosphate group
Stearic acid

Cholesterol

- **Cholesterol** is a type of fat (lipid) in human blood. Body cells need cholesterol, and body itself makes all it needs. But body also gets cholesterol from the food we eat.
- If we have too much cholesterol, it starts to build up in our arteries. (arteries are the blood vessels that carry blood away from the heart.) This is called hardening of the arteries, or atherosclerosis . It is the starting point for some heart and blood flow problems. The buildup can narrow the arteries and make it harder for blood to flow through them. The buildup can also lead to dangerous blood clots and inflammation that can cause heart attacks and strokes.
- There are different types of cholesterol:
- **LDL** (low-density lipoprotein) is the **"bad" cholesterol**. It's the kind that can raise risk of heart disease, heart attack, and stroke.
- **HDL** (high-density lipoprotein) is the **"good" cholesterol**. It's the kind that is linked to a lower risk of heart disease, heart attack, and stroke.

Cholesterol Count

- **Total** cholesterol
- **Good:** 170 mg/dL or lower; **Borderline:** 170 to 199 mg/dL
- **High:** 200 mg/dL or higher
- **LDL** (low-density lipoprotein):
- **Good:** 110 mg/dL or lower; **Borderline:** 110 to 129 mg/dL
- **High:** 130 mg/dL or higher
- **HDL** (high-density lipoprotein):
- **Good:** 45 mg/dL or higher; **Borderline:** 40 to 45 mg/dL
- **Low:** 40 mg/dL or lower

Function of Lipids

Lipids perform several important functions:

1. They are the concentrated fuel reserve of the body (triacylglycerols). They provide energy at 9 k.cal/g
2. Lipids are the constituents of membrane structure and regulate the membrane permeability (phospholipids and cholesterol).
3. They serve as a source of fat soluble vitamins (A, D, E, K)
4. Lipids are important as cellular metabolic regulators (steroid hormones and prostaglandins).
5. Lipids protect the internal organs, serve as insulating materials and give shape and smooth appearance to the body.

Hormones are chemical substance that are secreted from different cells or glands of human body and act upon their respective target cells or organs. E.g. sex hormones, insulin hormones.

A steroid is an organic compound with four rings arranged in a specific configuration. Examples include the dietary lipid cholesterol, the sex hormones estradiol and testosterone.

Use of Fates and Oils

1. **Fats and oils** are used for frying and cooking, providing a controlled heat exchange medium as well as changing the colour and flour of cooked foods.
2. As **shortenings**, they impart a 'short' or tender quality to baked goods through a combination of lubrication and an ability to alter the interaction among other food constituents.
3. **As salad oils**, they contribute to mouth feel and also function as a carrier of flavours.
4. When emulsified with other ingredients they function as a carrier of flavours in the form of viscous pourable dressings or semi-solid fatty foods known as mayonnaise or salad dressings.
5. **Margarine** (imitation butter) is used both for baking and cooking and also as a table spread.
6. Specially selected or manufactured fats are useful in confections, especially as enrobing or coating agents. These fats have a short melting range at body temperature.

Dietary Sources of Fats and Oils

Dietary requirement and sources of fats and oils are:

1. The dietary fat intake for providing about 40% of the total energy requirement of an adult has been calculated to be in the range of 100 to 150 g/day.
2. The various **sources of fats** include meat of animals (cattle, goat, pig, sheep etc.) , eggs, fish, milk, legumes, fruits and vegetables.
3. The various **sources of oils** include cereals, soybean, olive, seeds of sunflower, cotton seeds, corn, peanut and mustard.
4. **Fates and oils are available** in a variety of forms such as, cooking oils, salad oils, shortenings, margarines, etc.
5. **Salad and cooking oils** are prepared from the oils of cotton seed, soybean, corn, peanut, olive, seeds of sunflower and mustard.

Dietary Sources of Fats and Oils

5. **Margarines are prepared** from fats and oils of plant as well as animal origin with other ingredients such as milk solids, salt, flavouring materials, and vitamins A and D. The fat content in margarines is about 80%.

6. **Butter is obtained** by churning cream is a water-in-oil emulsion containing 80% milk fats in a plastic form.

7. **Coca butter obtained from** cocoa beans is the preferred fat in confectionery.

8. Commercial shortenings are semisolid plastic fats made from lard, tallow, cotton seed oil or soybean oil with or without emulsifying agents.

Fatty Acids

Fatty Acid: F**atty acid** is a carboxylic acid with a long aliphatic chain, which is either saturated or unsaturated. Most naturally occurring fatty acids have an unbranched chain of an even number of carbon atoms, from 4 to 28. Fatty acids are usually derived from triglycerides or phospholipids. Fatty acids are important sources of fuel because, when metabolized, they yield large quantities of ATP.

Even and odd carbon fatty acids: Most of the fatty acids that occur in natural lipids are of even carbons (usually 14C–20C). This is due to the fact that biosynthesis of fatty acids mainly occurs with the sequential addition of 2 carbon units. Palmitic acid (16C) and stearic acid (18C) are the most common. Among the odd chain fatty acids, propionic acid (3C) and valeric acid (5C) are well known.

Saturated and unsaturated fatty acids: Saturated fatty acids do not contain double bonds, while unsaturated fatty acids contain one or more double bonds.

Saturated and Unsaturated Fatty acids

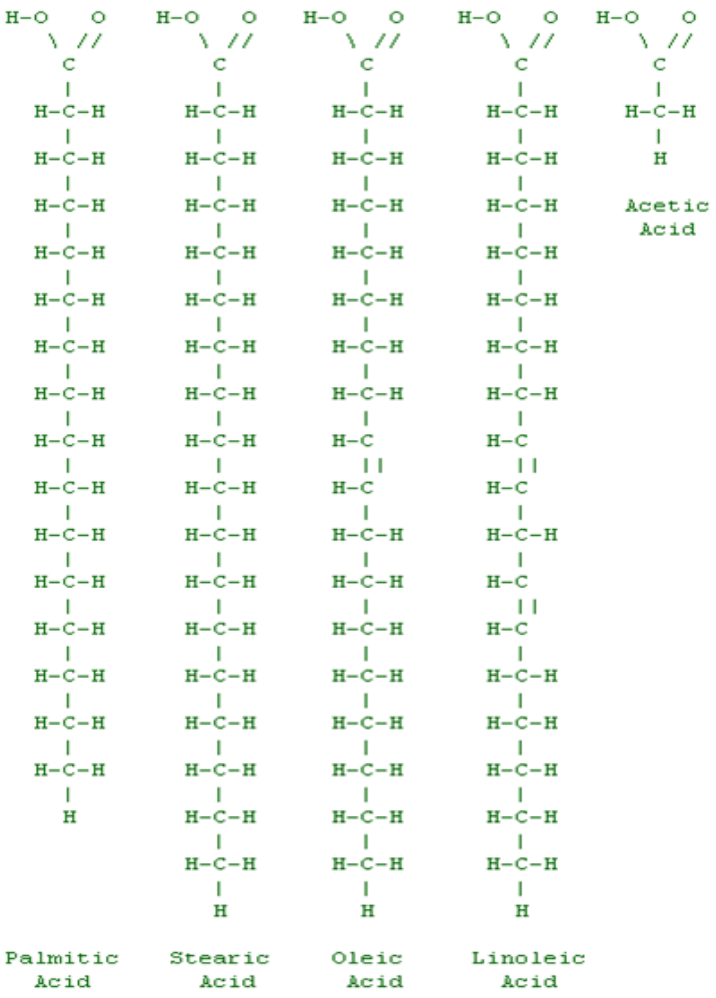


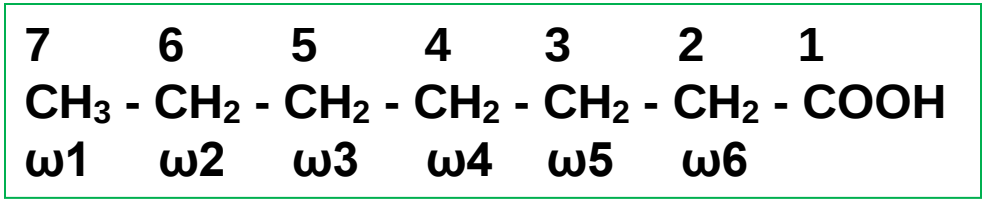
Fig. Saturated vs unsaturated fatty acids

Saturated Fats: In the figure, palmitic acid and stearic acid, the carbon chains are completely and evenly filled with hydrogen atoms. In other words, the chains are **saturated** with hydrogen. Fats (triglycerides) that contain palmitic acid and stearic acid are therefore known as **saturated fats**. Fats made up of saturated fatty acids are solid at room temperature.

Unsaturated Fats: In case of oleic acid, carbon chain is not saturated. Two of the carbons are connected by a double bond, and two of the hydrogen atoms are missing. This fatty acid is called **unsaturated**. Fats that have a lot of oleic acid in them are liquid at room temperature, and are therefore known to us as **oils**. Oleic acid, because it contains one double bond, is also referred to as **mono-unsaturated**. Fatty acids that have multiple double bonds, like linoleic acid, are called **polyunsaturated**. Polyunsaturated fats are also liquid at room temperature.

Length of Hydrocarbon chain and Numbering of Carbon atoms of Fatty Acids

- **Length of hydrocarbon chain:** Depending on the length of carbon chains, fatty acids are categorized into 3 groups:
- **Short chain** (with less than 6 carbons);
- **Medium chain** (with 8 to 14 carbons) and
- **Long chain** (with 16 to 24 carbons).
- **Numbering of carbon atoms:** It starts from the carboxyl carbon which is taken as number 1. The carbons adjacent to this are 2, 3, 4 and so on or alternately α, β, γ and so on. The terminal carbon containing methyl group is known as omega (ω) carbon. Starting from the methyl end, the carbon atoms in a fatty acid are numbered as omega 1, 2, 3 etc. The numbering of carbon atoms in two different ways is given below:



Essential Fatty Acid

- **Essential Fatty Acids:** The fatty acids that cannot be synthesized by the body and, therefore, should be supplied in the diet are known as essential fatty acids (EFA). Chemically they are polyunsaturated fatty acids, namely

1. Linoleic acid (18: 2; 9,12),

$CH_3(CH_2)_4CH = CHCH_2CH = CH(CH_2)_7COOH$, and

2. Linolenic acid (18: 3; 9, 12, 15),

$CH_3CH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_7COOH$

Arachidonic acid (20: 4; 5, 8, 11, 14),

$CH_3(CH_2)_4CH = CHCH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_3COOH$

becomes essential, if its precursor linoleic acid is not provided in the diet in sufficient amounts.

Biochemical basis for essentiality: Linoleic acid and linolenic acid are essential since humans lack the enzymes that can introduce double bonds beyond carbon 9 to 10.

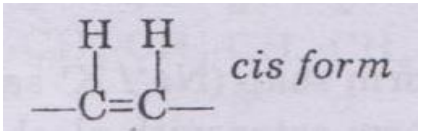
Essential Fatty Acid

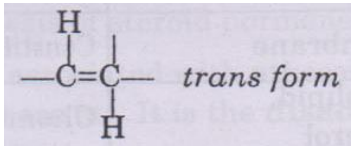
- **Function of EFA:** Essential fatty acids are required for the membrane structure and function transport of cholesterol, formation of lipoproteins, prevention of fatty liver etc. They are also needed for the synthesis of another important group of compounds, namely eicosanoids.
- **Deficiency of EFA:** The deficiency of EFA result in phrynoderma or toad skin, characterized by the presence of horny eruptions.

CIS and Trans FA and Trans Fat

Cis Fatty Acid: Double bonds (C=C) of natural unsaturated fatty acid are arranged in cis isomeric form with both hydrogen atoms on the same side of double bonds. This makes the unsaturated fatty acid more fluid.

Trans fatty acid: Double bonds (C=C) of unsaturated fatty acid can also be trans isomeric form with hydrogen atoms on the opposite side of double bonds. This makes the fatty acid less fluid. Therefore, trans fatty acids behave like saturated fatty acid

cis form 



trans form

- Trans fatty acid are not commonly found in nature; however, they can be produced as a byproduct during hydrogenation (addition of H_2 to organic molecule) treatment on poly unsaturated fatty acid of natural oils to make it harden fat. E.g. solid margarine (hydrogenated vegetable oil). Trans fatty acid containing TAG is called trans fat.

Importance: Consumption of trans fatty acid and trans fat elevate LDL & decrease HDL. So, they increase the risk of coronary artery disease & diabetes mellitus (metabolic diseases in which there are high blood sugar levels over a prolonged period).

The End