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:** Lipids are heterogeneous group of organic compounds (including fats, oils, steroids, waxes and related compounds) which are related more by their physical properties than by their chemical properties. They have the common properties of being:
  - 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.

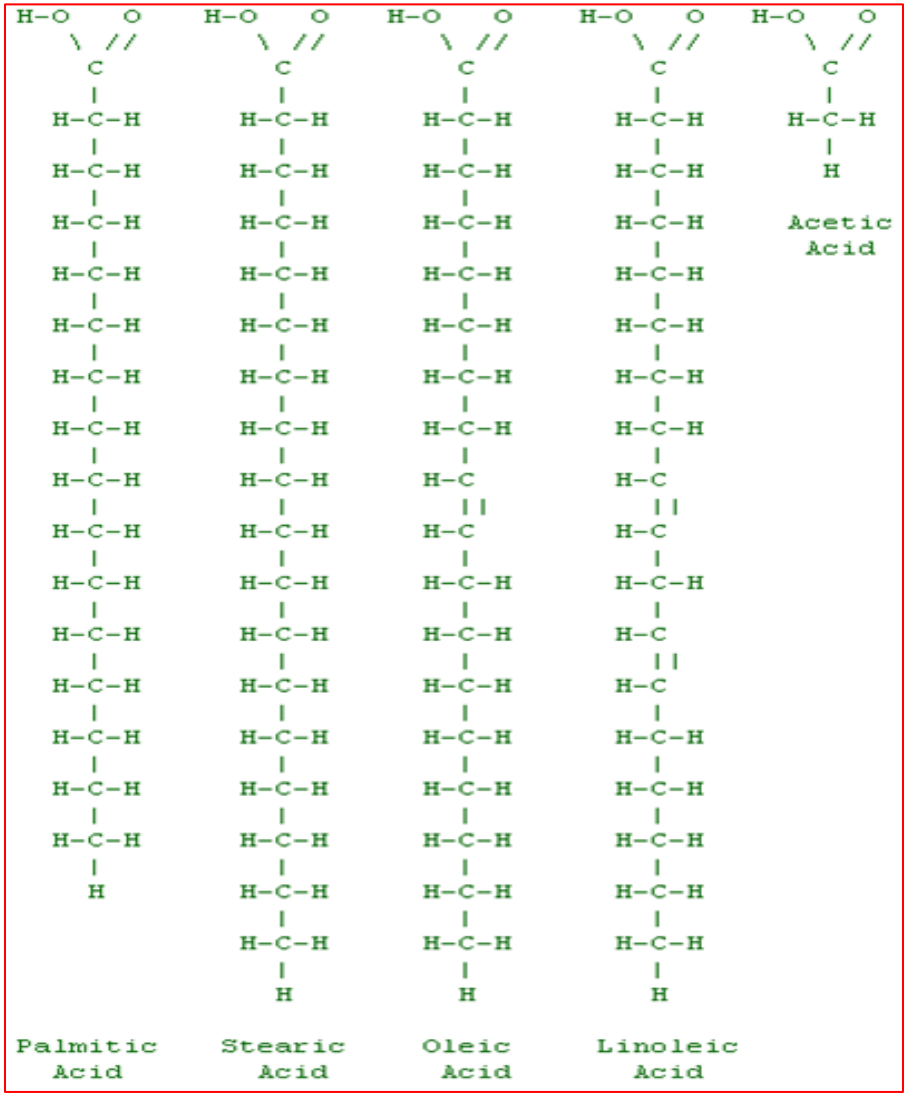
Saturated and Unsaturated Fatty Acid

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 (saturated)
2. Stearic acid (saturated)
3. Oleic acid (unsaturated)
4. Linoleic acid (unsaturated)
5. Acetic acid (ethanoic acid) (saturated)



Classification of Lipids

Lipids are broadly classified into 3 classes:

Simple, Complex and Derived lipids

1. **Simple lipids:**. e.g. Neutral fat and Wax

- Esters of fatty acids with alcohols, containing no non-lipid substance
- Basically composed of fatty acid + alcohol ;

2. Complex (Compound) Lipid: e.g. Phospholipid, glycolipid & lipoprotein.

- Estes of fatty acid with alcohol along with other non lipid substances.
- Basically composed of fatty acid + alcohol + other non lipid substance.

3. Derived Lipid

- Derivatives obtained by hydrolysis of simple lipid and complex lipid which still possess the general characteristics of lipid,
- e.g. fatty acid, alcohol, glycerol, steroid, cholesterol, prostaglandins, fat soluble vitamins, ketone body etc.

Classification of Lipids

Simple lipids are of two types.

(a) Neutral Fat: (triacylglycerols):

- Triester of fatty acids with glycerol.
- It is also called triglyceride (TG) or triacylglycerol (TAG).
- Chemically they are composed of one glycerol molecule with three fatty acids, and they are regarded as neutral because they do not have any charge at normal body $P^{H.}$
- Fat in liquid state is called oil e.g. vegetable oil, fish oil.
- Fatty acid found in neutral fat are mostly palmitic acid, stearic acid and oleic acid.
- Neutral fat of plant source (e.g. vegetable oil) have more unsaturated fatty acid and that of animal source (e.g. ghee, egg etc.) have more saturated fatty acid.

Classification of Lipids

(b) Waxes:

- Esters of fatty acid with long chain monohydric alcohol (other than glycerol). Example of monohydric alcohol: methanol, ethanol etc.
- e.g. Retinol ester (Retinol + fatty acid). Cholesterol ester (Cholesterol + fatty acid). Vitamin D ester (Vitamin D + fatty acid)
- These alcohols may be aliphatic or alicyclic.

Difference between fat and oil

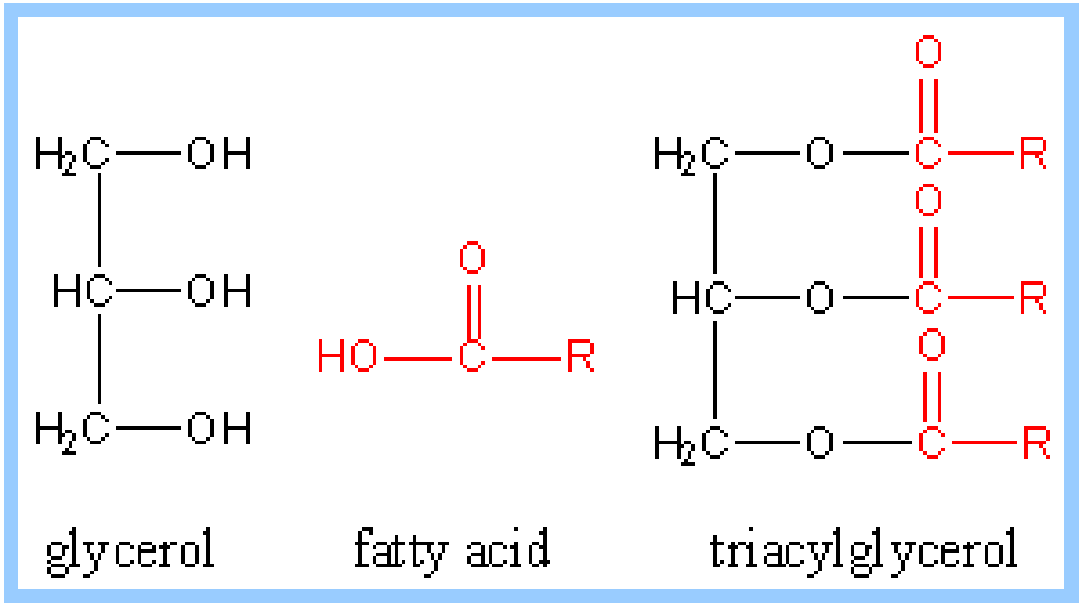
Fat	Oil
Solid at room temperature (25^{o}C)	Liquid at room temperature
Contain more saturated fatty acid	Contain more unsaturated fatty acid

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.

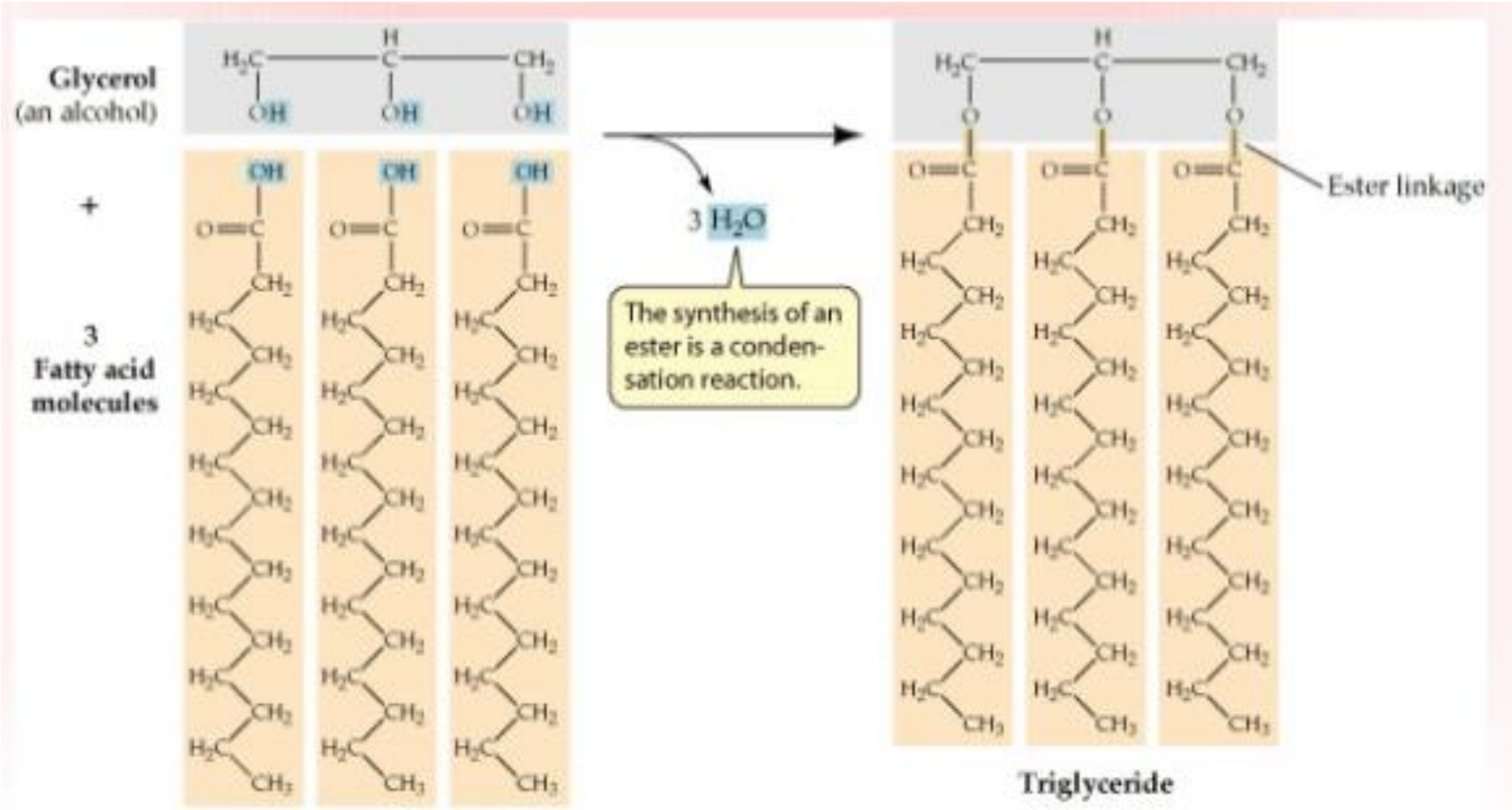
- **Glycerol** (also called glycerine or glycerin) is a simple polyol (an alcohol containing multiple hydroxyl groups) compound. It is a colorless, odorless, viscous liquid that is sweet-tasting and non-toxic. The glycerol backbone is found in all lipids known as triglycerides. It is widely used in the 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)

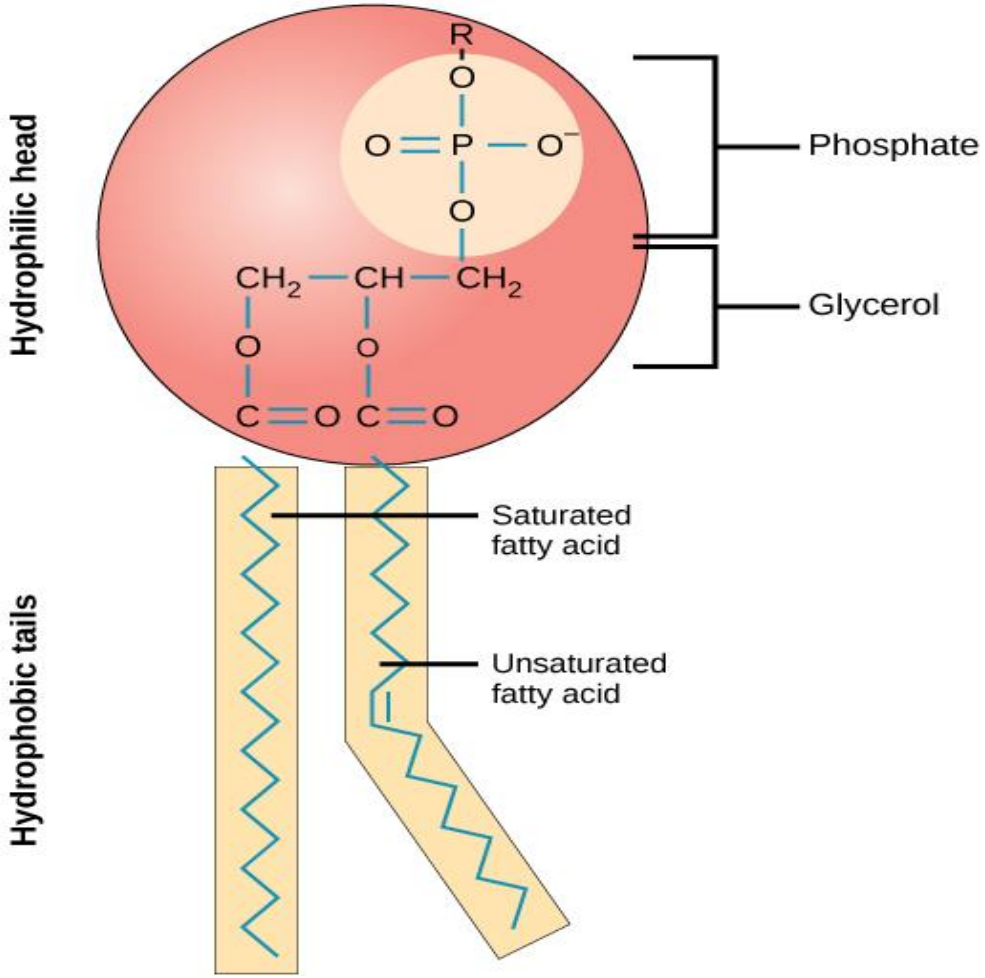


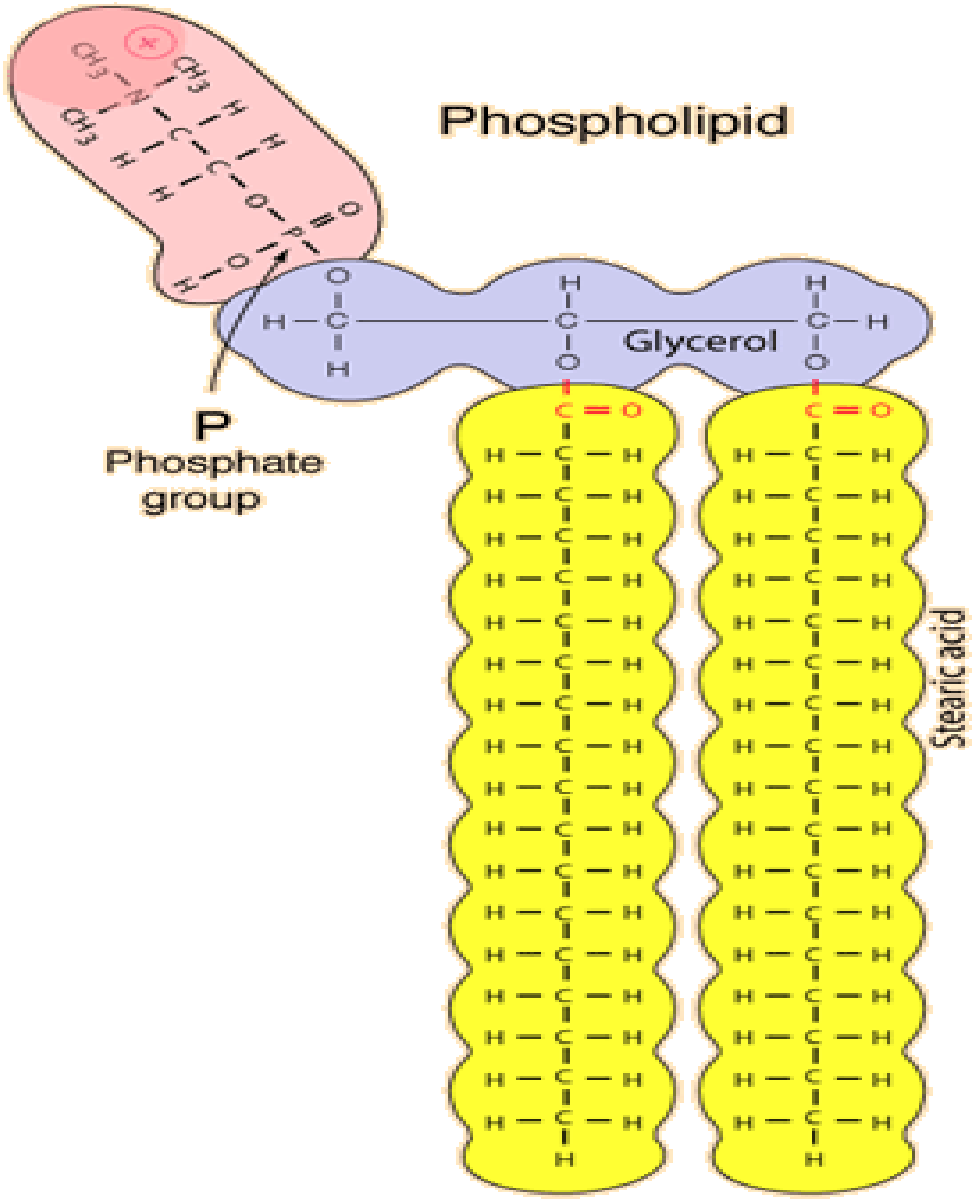
Fats and Oils are triglycerides, composed of three fatty acids covalently bonded to a glycerol molecule by ester linkages.

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 flavour 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 of fats and oils are:

- 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.

Dietary sources of fats and oils are:

1. The various **sources of fats** include meat of animals (cattle, goat, pig, sheep etc.) , eggs, fish, milk, legumes, fruits and vegetables.
2. The various **sources of oils** include cereals, soybean, olive, seeds of sunflower, cotton seeds, corn, peanut and mustard.

Fatty Acids

Fatty Acid (FA):

- F**atty acid** is a carboxyl (-COOH) group containing organic acid with a long aliphatic hydrocarbon chain, which is either saturated or unsaturated. Most naturally occurring fatty acids have an unbranched hydrocarbon 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. More than 90% of fatty acid in human body contains even number of carbon (mostly with carbon number 14 to 24) and less 5% contains odd number of carbon atoms.

Sources of Fatty Acid:

Endogenous source: Synthesis of non essential fatty acid within the body.

Exogenous (Dietary) sources:

- For saturated fatty acid: animal fat, milk, butter, ghee, dalda, coconut oil, palm oil, vanaspati (hydrogenated fat)
- For unsaturated fatty acid: vegetable oil, fish oil, codliver oil, egg yolk.

Classification of Fatty Acids

Classification of fatty acid:

A. Based on the total number of carbon (chain length):

1. **Short chain fatty acid (carbon number < 10):** Mostly found in milk. e.g. Acetic acid (2 C), propionic acid (3 C), Butyric acid (4C) etc.
2. **Long chain fatty acid (carbon number >10):** e.g. Palmitic acid (16C), stearic acid (18C) etc.

B. Based on the even or odd number of carbon:

1. **Even 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.
2. **Odd carbon fatty acid:** Among the odd chain fatty acids, propionic acid (3C) and valeric acid (5C) are well known.

Classification of Fatty Acids

Classification of fatty acid:

C. Based on saturation of carbon:

1. Saturated fatty acids:

- They do not contain any double bond in their hydrocarbon chain.
- They represent about 50% of body fatty acid pool & usually remain solid at room temperature.
- E.g. palmitic acid (16C), stearic acid (18C), butyric acid (4C), acetic acid (2C)

2. unsaturated fatty acids:

- They contain one or more double bond in their hydrocarbon chains. Double bonds are nearly always in cis form.
- They represent about 50% of body fatty acid pool and usually remain liquid at room temperature.

Classification of Fatty Acids

Again Unsaturated fatty acids are classified as:

a. Monounsaturated fatty acid MUFA):

- They contain one double bond.
- Found in olive oil, canola oil.
- E.g. oleic acid (18C), palmitoleic acid (16C)

b. Polyunsaturated fatty acid (PUFA):

- They contain >= 2 double bond.
- Found in fish oil & vegetable oil (except coconut oil and palm oil)

Saturated and Unsaturated Fatty acids

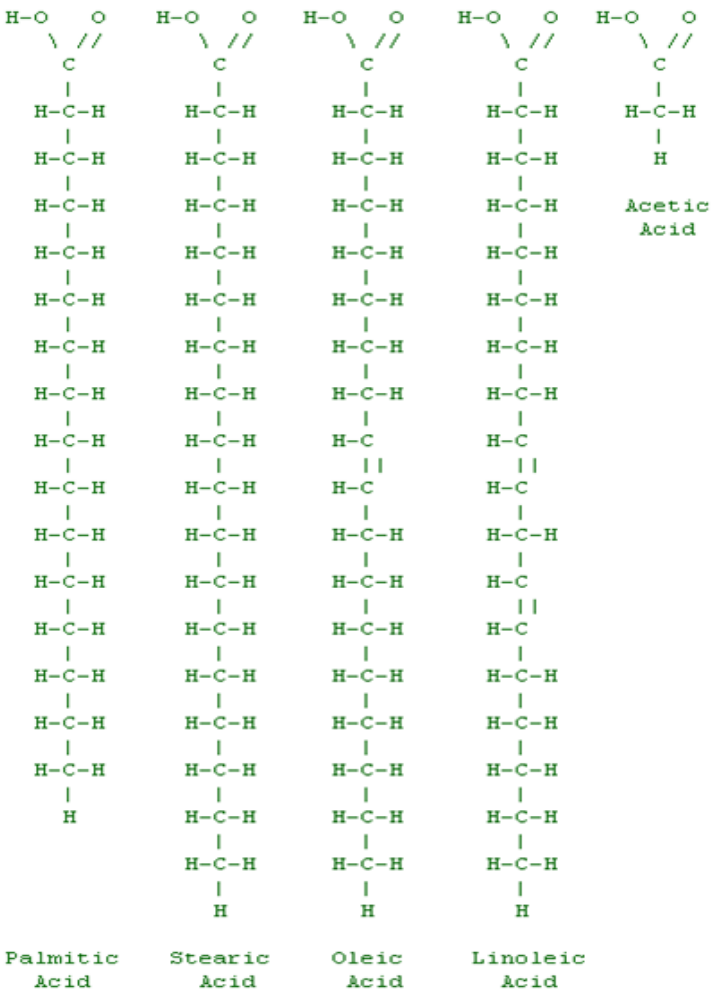


Fig. Saturated vs unsaturated fatty acids

Saturated Fatty acids: 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 Fatty acids: In case of oleic acid, and linoleic 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 as **oils**. Oleic acid, because it contains one double bond, is also referred to as **mono-unsaturated fatty acid**. Fatty acids that have multiple double bonds, like linoleic acid, are called **polyunsaturated** Fatty acid. Polyunsaturated fats are also liquid at room temperature.

Classification of Fatty Acids

D. Nutritional classification of Fatty Acid:

1. Non essential fatty acid:

- These are the fatty acids which body can sysnthesize.
- e.g. palmitic acid, stearic acid, oleic acid etc.

2. Essential fatty acid (EFA):

- These are polyunsaturated fatty acid (PUFA) which are not produced in human body and must be supplied with diet.
- Essential fatty acid for human body are:

a. Linoleic acid (18: 2; 9,12); (ω_6 fatty acid) with 2 double bonds.

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

b. Linolenic acid (18: 3; 9, 12, 15); (ω_3 fatty acid) with 3 double bonds.

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

c. Arachidonic acid (20: 4; 5, 8, 11, 14), (ω_6 fatty acid) with 4 double bonds.

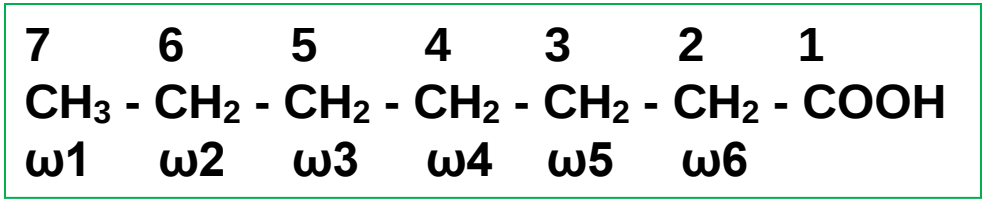
$CH_3(CH_2)_4CH = CHCH_2CH = CHCH_2CH = CHCH_2CH = CH(CH_2)_3COOH$

Numbering of Carbon atoms of Fatty Acids

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.

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, omega 2, 3 etc.
- The numbering of carbon atoms in two different ways is given below:



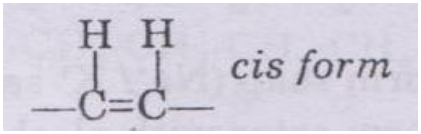
Essential Fatty Acid

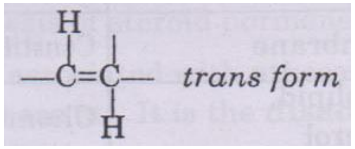
- **Function of EFA:** Essential fatty acids are required for the membrane structure and function transport of cholesterol, formation of lipoproteins, prevention of fatty liver etc. They are also needed for the synthesis of another important group of compounds, namely eicosanoids.
- **Deficiency of EFA:** 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).

Thanks